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THE PINE TREES OF THE ROCKY MOUNTAIN REGION.

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SCOPE OF THE BULLETIN.

In this bulletin are described and figured the distinguishing characteristics of all of the pine trees that inhabit the Rocky Mountain region. Graphic illustrations of the range of these trees and discussions of their forest habits are also included. The exact limits of the Rocky Mountain territory covered by this publication are given in Bulletin No. 207[1] of the Forest Service, to which the reader is referred. Other statements made there regarding the general plan of treating the subject, sources of information, and acknowledgments of assistance[2] received apply to the present bulletin. The

[1] "The Cypress and Juniper Trees of the Rocky Mountain Region, 1915.

[2] Grateful acknowledgment is here made to Dr. H. N. Whitford for valuable notes on the range of *Pinus manticola* and *P. albicaulis* in British Columbia.

reader will also find full information in Bulletin 207 regarding the class and family relationship of the pines to other coniferous trees of the Rocky Mountains.

GENERIC CHARACTERISTICS OF PINES.

All of the pines are evergreen trees, their branches being more or less thickly clothed with clusters of leaves which are needlelike and borne in bundles or fascicles of 1, 2, 3, 4, or 5.[1] When the leaves first appear, they have a basal sheath of scales, in some cases very thin and in others thicker and stiff. In some pines these scales are retained until the leaves die, while in others they are shed when the leaves become fully grown. The leaves vary in length from about 1 to 15 inches. The juvenile or primordial form of leaf borne on the first shoot of seedling pines differs from the adult form by being single, this form soon being followed by adult or true foliage leaves. Seed-leaves (cotyledons) of pines, the first foliar organs produced when the seed germinates, are needle-shaped and from 3 to 15 in number. The leaves of pines vary from cylindrical, as in the single-leafed species, and half-round, as in two-leafed pines, to a triangular or three-edged leaf in the 3- to 5-leafed species. The edges of the leaves of some pines are provided with minute teeth, while those of others are smooth. The color of the leaves ranges from a blue or silvery green to a deep yellow-green, the surfaces bearing lines of minute pores or stomata. In cross section the leaves of pines show from 2 to 14 minute resin ducts, the position and number of which vary in different species. A new set of leaves is formed each year on the young twigs. The leaves produced each season may remain on the tree from 2 to 6 or 8 years, during which they maintain their green color and vegetative activity. When a set of new leaves is being formed at the ends of the new twigs, the oldest set of leaves, situated farther back on the branches, dies and falls to the ground. The winter buds of pines are variable in form and in size, and all are covered by fringed or papery-margined overlapping scales. The component scales each protect a tiny bud, which, when the main bud unfolds in the spring, develops into a fascicle of leaves or, in some cases, into a female flower.

The flowers of the pines are male and female, borne usually on different branches of the same tree. Male flowers, which produce pollen, are short, oval, and budlike, or long cylindrical bodies, clustered at the ends of mature leafy branches. In color they are bright

[1] Remarkable variations occur in the generally regular number of leaves borne by the 2- 3- 4- and 5-leafed pines, a 2- or 3-leafed species occasionally or frequently having a number of 3- and 4-leafed fascicles, while the 4- and 5-leafed pines may have some fascicles with 5, 6, or 7 leaves. Whether or not these variations represent gradual transitions from one type to a different type of foliar habit can not be affirmed at present.

red, yellow, or orange. The female flowers, which produce cones and seed, are small, greenish, scaly, conelike bodies, produced singly or in pairs or larger groups near the ends of young growing shoots. After fertilization of one or both of the two ovules (under each scale) the female flowers develop into small cones during the first season, completing their growth at the end of the second or third summer.

The fruits of pines are woody, scaly cones, matured in 2 or 3 years. Each of the scales in the central portion of the cone usually bears 2 seeds at its base and on the under side. The cones of some pines remain on the trees only a few weeks after ripening, while those of others persist for many years; or they may be so firmly attached that finally they become entirely enveloped by the annual diameter growth of the branch or trunk and never leave the tree. Within a few weeks after maturity most pine cones open under the heat of the sun and liberate their seeds. The cones of a few pines, however, may remain closed for several or for many seasons, sometimes opening fully only under the heat of a forest fire. The cones of one of our pines (*Pinus albicaulis*) never open naturally, the seeds not being liberated until the scales rot by contact with the ground. This peculiar retention of the seeds explains in part at least how certain pines often reproduce themselves after the original forest has been killed by fire, since not all of the cones are burned enough to destroy their seeds, which are scattered after the fire.

Mature cones vary in length, according to the species, from an inch to 2 feet, and in diameter from three-fourths of an inch to 6 or 8 inches. The seeds of most pines bear a thin papery wing at one end, the wing assisting greatly in the distribution of the seed (Pl. I, *c*, *d*). In a few species, however, the seeds have only the rudiment of a wing, which remains attached to the cone scales, thus rendering the seed wingless when it is shed (Pl. X, *e*). The piñon or "nut" pines bear wingless seeds, which, unlike winged seeds, are dependent for their distribution on such accidental agencies as flood waters and mammals. Pine seeds vary in size from one-half that of a kernel of wheat to nearly the size of a small hazelnut.[1]

The pines are among our most important commercial trees. Most of them have straight, unbranched, cylindrical trunks, which furnish large amounts of excellent saw timber. On account of the straight grain, strength, and other qualities of pine timber it is used for nearly every sort of construction work.

The large quantities of naval stores used in the United States, or exported to other countries, are derived by distillation from the crude

[1] Pine seeds are the favorite food of many birds, and of squirrels and other rodents, which doubtless consume large quantities. Seeds of the "nut" pines are also gathered extensively by western Indians and settlers for food. Mammals, however, often assist in distributing pine seeds through their habit of caching the seeds in the ground where those not eaten may later germinate.

resin of the heavy, more resinous-wooded pines. All of the pines yield resin in greater or less quantities, but so far the commercial qualities of only a few of these resins have been determined. In recent years the wood of pine stumps and old logs is also being distilled for turpentine, this product being known as wood turpentine.

Some 70 species of pines are known in the world. Thirty-six of them inhabit the United States, 14 of which occur in the Rocky Mountain region. Six of these Rocky Mountain species occur also in the Pacific slope region, and one ranges eastward from the Rockies in Canada into the Atlantic coast country.

Pines are of ancient origin, some of them having existed in North America and Europe in the Cretaceous and Miocene periods.

WHITE PINES.

Trees with light, soft wood in which the early and late formed portions of the annual rings are not sharply defined.

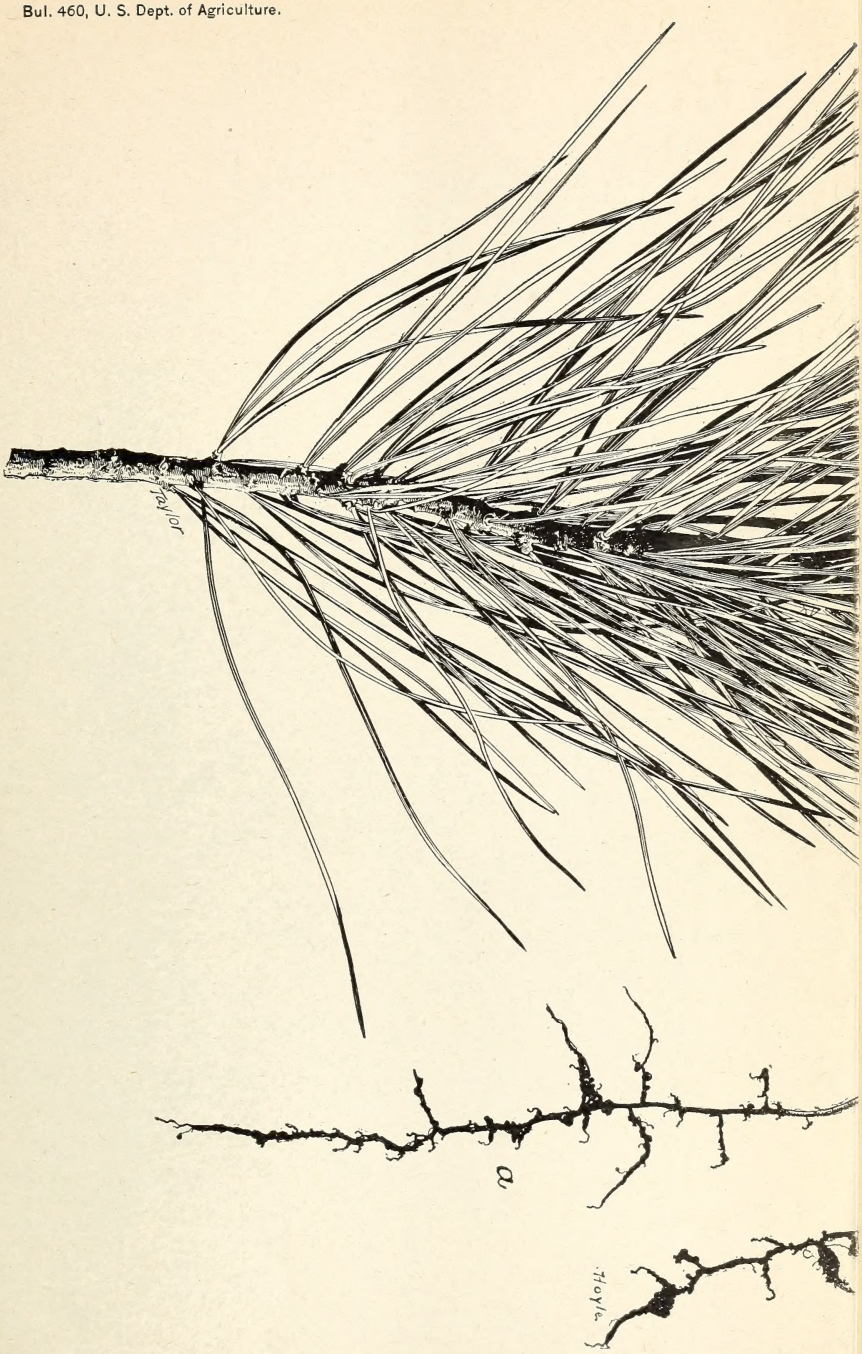
WESTERN WHITE PINE.

Pinus monticola Douglas.

COMMON NAME AND EARLY HISTORY.

Pinus monticola is now properly known as western white pine. It is hoped that this name may be widely accepted in order to avoid confusing *Pinus monticola* with its eastern relative, *Pinus strobus*. For a number of years it was known to western lumbermen and manufacturers as "Idaho white pine" and "Montana white pine," because the commercial supply of lumber came from forests in northern Idaho and northwestern Montana. It is also called "white pine," probably on account of the similarity of its wood to the well-known white pine (*Pinus strobus*) of northeastern United States and adjacent Canadian territory. The book names "silver pine," referring to the silvery-green hue of the foliage, and "mountain Weymouth pine," based partly on the tree's technical name and partly on an English name for *Pinus strobus*, are not in current use.

Western white pine was discovered by that redoubtable Scotch explorer of our Northwest, David Douglas, who found it in 1831 near the Columbia River, whether in Oregon or Washington is unknown, but probably in Washington. The tree was technically described and named for the first time in 1837. The name then given to it, *Pinus monticola*, has been generally maintained and there has been little or no confusion of the western white pine with other white pines of its range. Because of its general resemblance to the eastern white pine (*Pinus strobus*), Nuttall described it in 1849 as a variety (*Pinus strobus* β *monticola*) of this species, from which, however, it is distinct. In 1888 and 1895 Dr. J. G. Lemmon distinguished two varie-

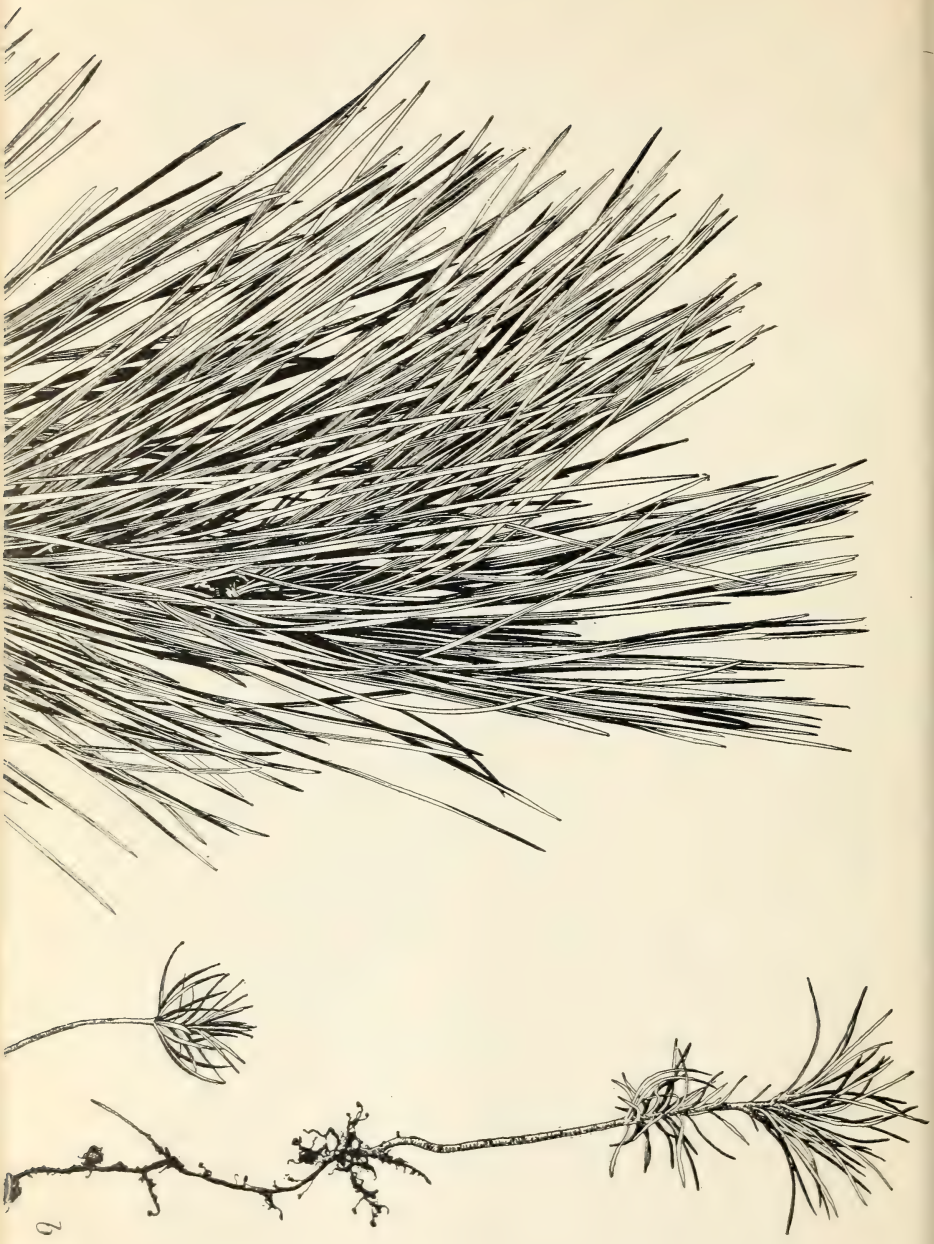


PINUS M

a, *b*, one- an

PINUS MONTICOLA.

a, Foliage; *b*, detached cones; seeds with wings; *c*, upper side; *d*, lower side.



ONTICOLA: FOLIAGE.

l two-year-old seedlings.

ties of the western white pine, *Pinus monticola minima* and *P. monticola digitata*, based on differences he recognized in the form and size of the cones. A purple-coned form of western white pine cultivated in England was described in 1866 as *Pinus porphyrocarpa* A. Murray, and later, in 1892, as *Pinus monticola* variety *porphyrocarpa* Masters. In the writer's judgment, none of these forms are worthy of specific or varietal distinction.[1]

DISTINGUISHING CHARACTERISTICS.

In dense forests, where its most characteristic form is found, this pine has a tall, slender shaft, with a peculiarly short-branched, narrow, symmetrical crown. The branches are usually slender and drooping, and in early life extend over one-half or two-thirds the length of the trunk. Its height ranges from 90 to 150 feet, and its diameter from 2½ to 5, or exceptionally, from 6 to 8 feet. In open forests, where the conditions of growth are less favorable to its better development, western white pine is a short-bodied tree, 50 or 60 feet in height, with one or more very long, stout, horizontal branches extending from 10 to 15 feet or more beyond the other slender branches. This striking characteristic distinguishes the tree as far as it can be seen.

The bark of trees a foot or more in diameter is distinctly broken into small, square blocks. No other tree associated with it has this bark characteristic. The bark of mature trees is rarely over 1¼ inches thick. In dense stands the color of the bark is grayish purple, while in open, windswept stands it is a distinct cinnamon-brown. The fierce winds of such locations constantly tear off the thin outer scales of bark and expose the red-brown interior. Young trees have thin, smooth, bright gray bark, as do also the branches and upper stems of old trees. The scaly winter buds are about one-half an inch long. During the first year the young twigs are deep yellowish brown and minutely hairy, but during the second year they become smooth.

The foliage of this pine is bluish green with a whitish tinge. That produced each season remains on the twigs until the third or fourth year. The leaves are from 2 to about 4 inches long and are borne in bundles of 5 (Pl. I, *a*; Pl. II). Their margins have minute widely separated teeth. The foliage of trees grown in exposed situations is

[1] Western white pine was introduced into England by David Douglas shortly after he discovered it in 1831. According to Elwes and Henry (Trees of Great Britain and Ireland, V, 1024, 1910) it was not common in cultivation there until 1851 or 1855. While perfectly hardy in England as regards cold, these authors find that it grows best in Scotland, particularly in moister situations. The largest trees planted in England are from 76 to 81 feet in height and from 20 to 32 inches in diameter. Some of these trees were planted as early as 1834 and 1847. *Pinus monticola* thrives in northeastern United States, where it has been planted as far north as western New York (Wyoming County) and eastern Massachusetts.

PINUS MONTICOLA: FOLIAGE.

a, *b*, one- and two-year-old seedlings.

denser (Pl. I, *a*) than that on trees in protected places or in close stands (Pl. II). A cross section of the leaf shows one or two resin ducts centrally situated near the border (back of leaf).

The cones are matured at the end of the second summer, usually by the first of September. They shed their seed soon afterward and fall from the trees within a few months. Mature cones (Pl. I, *b*) vary in length from about 6 to 10 inches; occasionally they are slightly longer or shorter. Before the mature cones become weathered by exposure the tips of the scales are red-brown or yellow-brown, the inner portion of the scales being a deep red. The seeds (Pl. I, *c*, *d*) are reddish brown, with small blackish spots. The seed-leaves vary in number from 6 to 9 (Pl. II, *a*, *b*).

The wood of western white pine is soft and of very light weight, a cubic foot of dry wood weighing about 24 pounds. The sapwood is nearly white and the heartwood is pale brown. The wood is very similar in appearance and in its working qualities to the wood of the eastern white pine (*Pinus strobus*), for which it is now extensively substituted.

OCCURRENCE AND HABITS.

Western white pine is not confined to any definite type of locality, but it occurs at an elevation of from about 2,000 in moist valleys, where it grows largest, to about 7,000 feet in dry, exposed, subalpine regions, where the trees are much smaller (Map No. 1). It is adapted to a variety of soils. The best growth, however, occurs where they are deep and porous. Regionally, the greatest development of western white pine is in northern Idaho and in adjacent parts of northwestern Montana, on gentle north slopes and flats. Lodgepole pine, Englemann spruce, western larch, western red cedar, alpine fir, grand fir, alpine hemlock, and western yew are variously associated with it in different parts of its range.

Western white pine endures considerable shade for a relatively long period during its seedling and later young growth, after which it requires abundant top light for its best development. Saplings or pole forms of the tree do not recover and grow well after they have been long suppressed by the shade of older trees.

This pine is not a prolific seeder. It bears cones only when about from 40 to 60 years old and at irregular intervals of about two years. As a rule, it reproduces itself sparingly. Seed germinates poorly on heavy humus, unless the latter is thoroughly and constantly moist; the best germination occurs on exposed, moist, mineral soil.

LONGEVITY.

Western white pine is a long-lived tree, attaining an age of from 200 to 500 years.

LIMBER PINE.

Pinus flexilis James.

COMMON NAME AND EARLY HISTORY.

Pinus flexilis is generally known in its mountain habitat as "white pine"; but as this name properly belongs to *Pinus strobus* of northeastern United States, the common name "limber pine," coined from the tree's technical name, *flexilis*, has been adopted. This name appropriately refers to the marked flexible quality of the twigs.

Limber pine was found first in 1820 near timber-line at the base of Pike's Peak, Colo., by Dr. Edwin James, a United States Army surgeon and naturalist attached to Stephen Harriman Long's expedition to the Rocky Mountains. Dr. James was also the first to name and describe this tree, his account of it being published in 1823. Since that time the botanical history of limber pine has been moderately free from confusion with related white pines of its range.[1]

DISTINGUISHING CHARACTERISTICS.

Pinus flexilis is a comparatively little-known species, doubtless because it grows chiefly in high places difficult of access. It is a low, thick-trunked, much-branched tree, from 25 to 50 feet in height, or sometimes 80 feet, with a short trunk from 12 to 30 inches in diameter; occasionally very old trees are from $3\frac{1}{2}$ to 4 feet in diameter. Young trees are peculiar for their regular distinct whorls of short, very tough branches, which stand out at right angles to the trunk and extend down to the ground. Middle-aged and old trees (from 75 to 200 years old) are characterized by extremely long and slender branches, especially near the ground and at the top; the latter are often 16 or 18 feet long and droop gracefully at a sharp angle with the trunk. These branches appear to develop entirely at the expense of the trunk, which remains stunted.

Large trunks have blackish or very dark-brown bark, which is from $1\frac{1}{2}$ to nearly 2 inches thick and deeply furrowed between the wide rectangular blocks; on trunks from 8 to 12 inches thick the bark is broken into small, thin, gray-brown plates. When separated, the scales expose a dull reddish inner bark. The thin, smooth bark of young pole-size trees and of branches is a bright whitish-gray, often

[1] Dr. C. C. Parry is said to have been the first to introduce this pine into cultivation, plants having been raised in the Harvard Botanic Garden from seed he collected in Colorado in 1861. The tree is possibly not adapted to our eastern climate, for the trees raised from Dr. Parry's seed attained a height of only about 5 feet in 35 years. Further planting of the tree at the Letchworth Park Forest and Arboretum, Wyoming County, N. Y., will later throw light upon this question. It appears to be better adapted to the climate of England, where, according to Elwes and Henry (The Trees of Great Britain and Ireland, V, 1048, 1910), three trees in Kew Gardens, probably grown from Dr. Parry's seed, had reached a height of 32 feet and about 11 inches in diameter in 1910. Other smaller trees planted in England are growing thriftily.

silvery. The exceedingly tough twigs are at first covered with fine, soft hairs, which soon disappear, leaving the branchlets quite smooth.

The dark yellow-green foliage is densely set at the ends of the branches. The leaves, borne in clusters of 5 (Pls. III, IV, V), are from about 1¾ to nearly 3 inches long. Each year's growth of leaves persists for approximately 5 years, a few sometimes remaining until the sixth year. The margins of the leaves bear minute widely separated teeth. A cross section of the leaf shows two resin ducts (on the back of the leaf) near the border; sometimes also there is a third resin duct near the inner or lower border of the leaf. The back (dorsal) side of the leaves is marked by from 1 to 4 lines of minute pores (stomata).

The cones (Pls. III to V) are mature in late summer or early autumn of the second year, and shed their seed in September or early in October. They are from 3½ to 10 inches long and peculiar in having the tips of their light yellowish-brown scales greatly thickened (Pl. III, *c*). The inner or concealed portions of the scales are pale red. By early winter the cones have fallen from the trees (Pls. III, *a;* IV, *a*). The seeds (Pl. III, *b*) are deep reddish brown and speckled with blackish brown. The seed-leaves are usually from 6 to 8 or sometimes 9 in number (Pl. V, *a*).

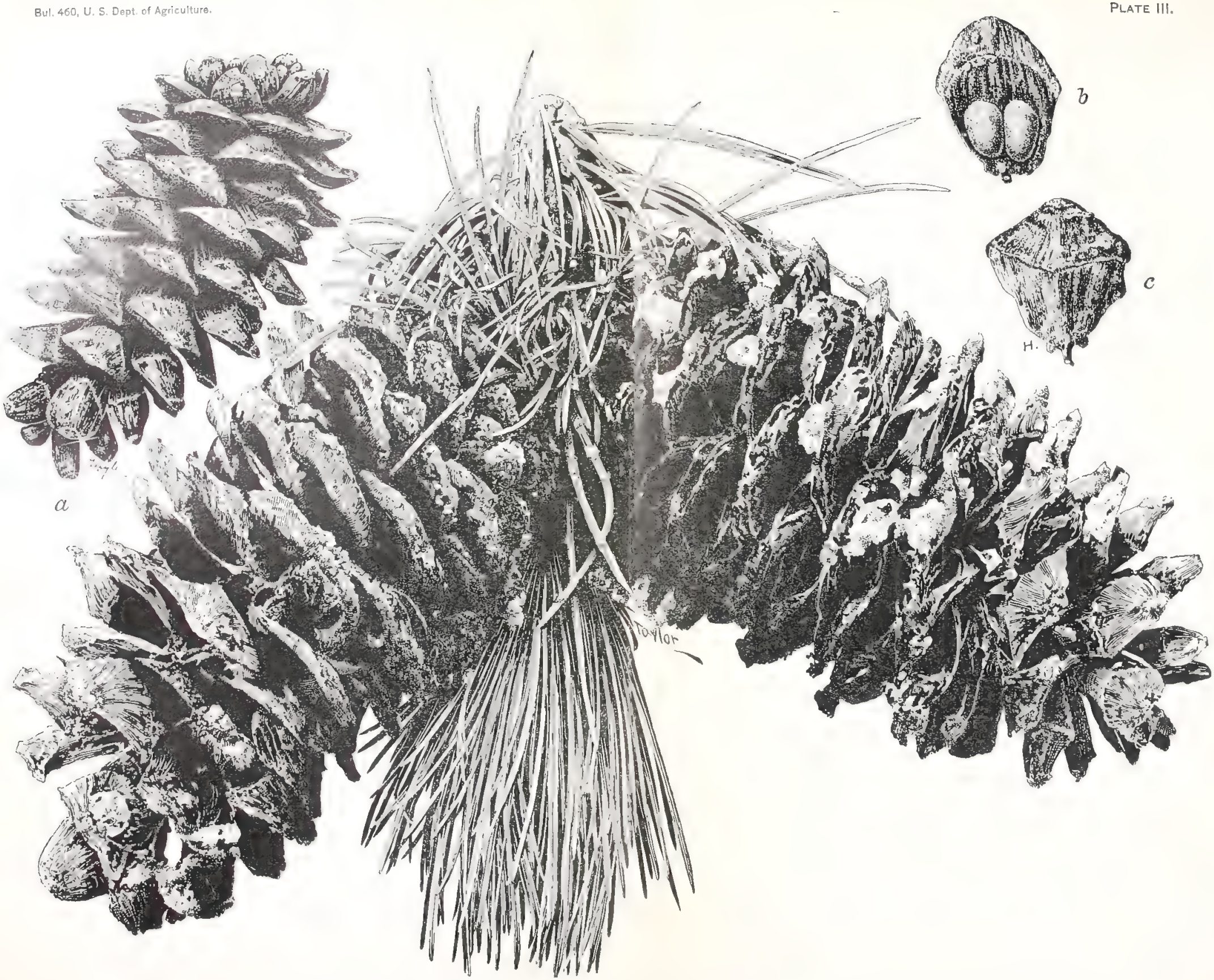
The wood of limber pine is very narrow-ringed, on account of the slow growth of the tree, and has only a thin layer of sapwood, which is nearly white. Freshly cut heartwood is a pale lemon-yellow. In texture the wood is rather soft but firm. A cubic foot of dry wood weighs about 27 pounds. Limber pine is occasionally cut for rough construction lumber which is used locally, the quality of the lumber being poor because of numerous knots. The wood is also used locally for fuel and sometimes for rough cabins and mine props.

OCCURRENCE AND HABITS.

Limber pine grows on dry, rocky, east slopes, summits, tops of ridges and foothills, and sometimes on the sides of moist canyons and banks of mountain streams, at elevations between 5,000 and 12,000 feet (Map No. 2). It is adapted to a great variety of soils and is not exacting as regards their depth or the amount of moisture, though it grows best in moist, well-drained soils. Usually it occurs in dry, rocky, very shallow soil, appearing to prefer dry gravelly loam with little or no humus. Limber pine reaches higher elevations on clay soils than it does on sandy ones, the higher ascent in clay soils being due to their greater retentiveness of moisture, which is especially favorable to seedling growth. This species is of much more frequent occurrence in the Rocky Mountain region than in the Pacific region.

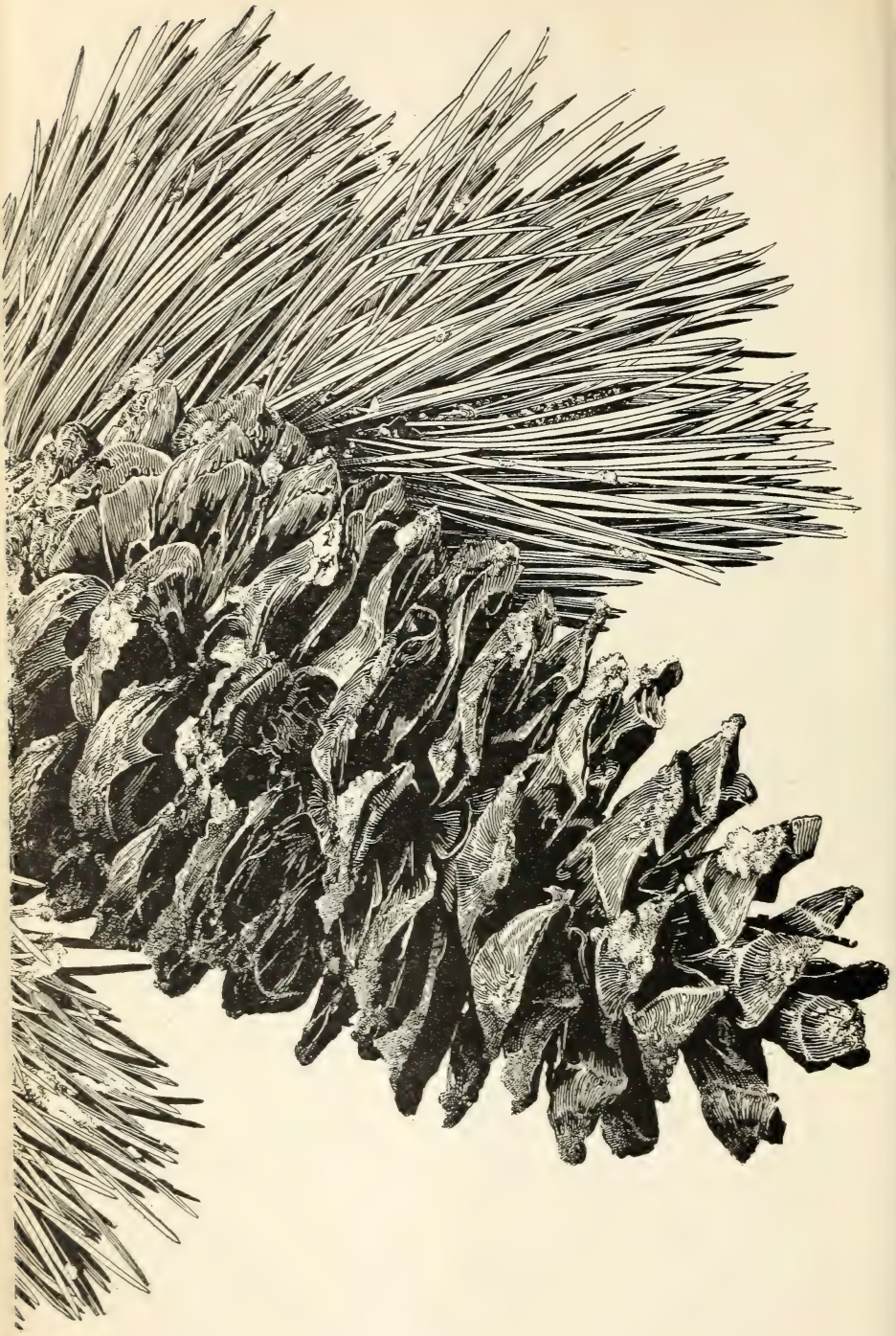
PINUS FLEXILIS: FOLIAGE

a, Detached



PINUS FLEXILIS: FOLIAGE AND LARGE FORM OF OPEN CONES (ATTACHED).

a, Detached small form of open cone; *b*, upper side of cone scale with its seeds; *c*, lower side of cone scale

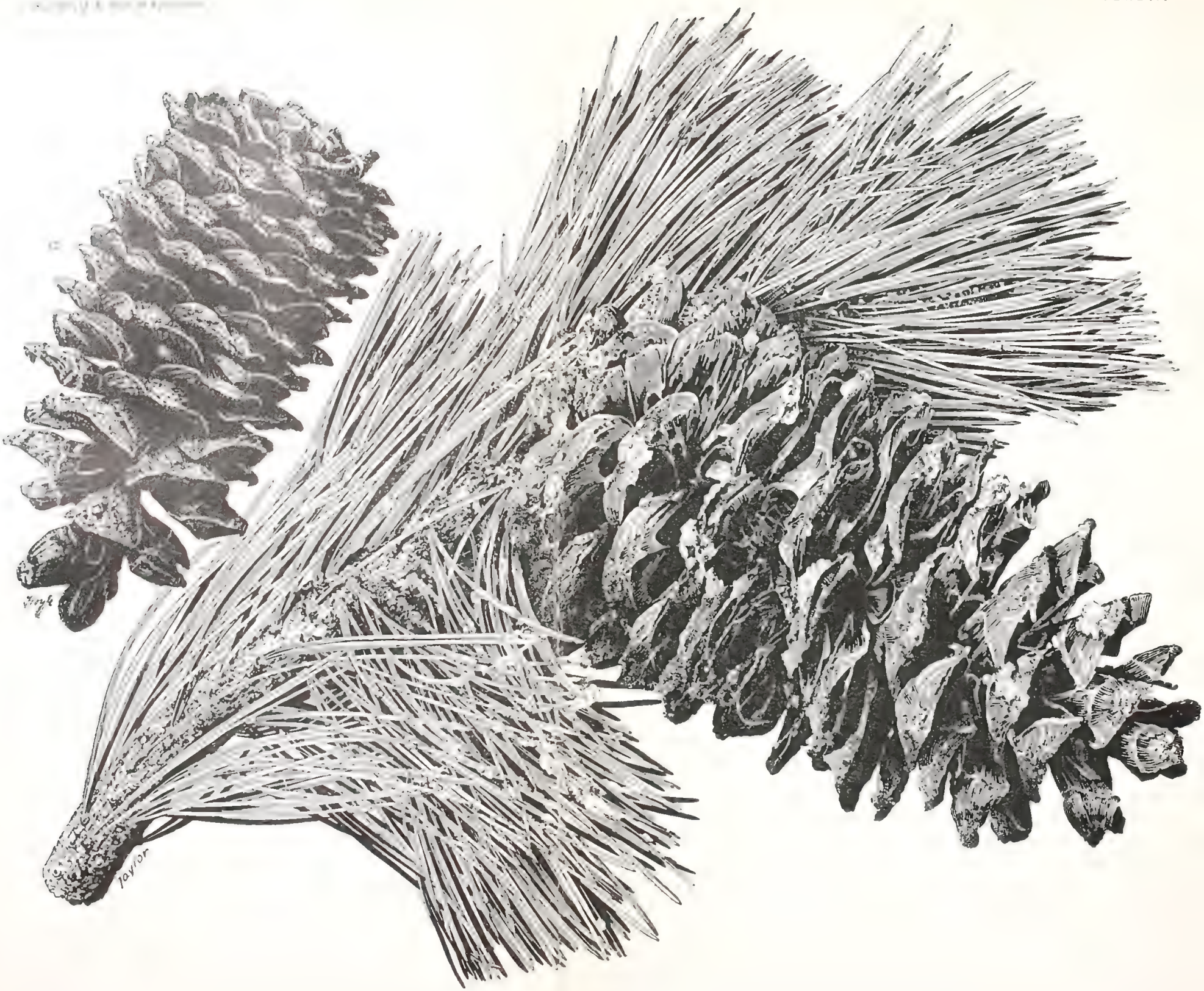


: AND LARGE FORM OF OPEN CONE.

small form of open cone,

PINUS FLEXILIS: FOLIAGE AND RIPE CLOSED CONE.

a, Seedling one month old (slightly less than natural size).



PINUS FLEXILIS: FOLIAGE AND LARGE FORM OF OPEN CONE.

a, Detached small form of open cone,

Pinus flexilis usually occurs interspersed among other conifers, singly or in small groves, the largest size being produced under these conditions. Occasionally, however, it forms pure, open growths of stunted trees on exposed slopes and ridges. It is associated mainly with lodgepole pine and mountain hemlock at higher elevations, and sparingly with white fir and Douglas fir at lower altitudes.

Limber pine grows best only in the full enjoyment of light, never forming dense stands. It is similar in its requirements of sunlight to the white-bark and bristle-cone pines, being less able to grow in the shade, except when young, than other associated conifers. Limber pine is not an aggressive tree and rarely crowds out other species. It is a moderate seeder, the amount of seed borne varying with the region and elevation. Generally it bears the largest number of cones in open stands at low altitudes, fruiting less abundantly in the denser stands and at higher elevations. The cones are produced locally about every year, while good seed years occur at intervals only of several years. Many of the seeds are eaten by birds and squirrels before they are shed. They are practically wingless and fall only near the trees. Flood waters distribute the seeds irregularly and the "hoards" of pine squirrels occasionally result in accidental planting of uneaten seed. Germination of the seed, which at best is only moderate, occurs most abundantly in moist mineral soil.

LONGEVITY.

Little is known now of the longevity of this pine. Trees from 18 to 22 inches through are from 200 to 300 years old.

WHITE-BARK PINE.

Pinus albicaulis Engelmann.

COMMON NAME AND EARLY HISTORY.

This species is commonly known to lay travelers in its high mountain habitat only as "scrub pine," because of its stunted form in exposed, wind-swept places. Those who know it botanically, however, usually call it white-bark pine, a name derived from the tree's technical name, *albicaulis* (white stem), which has reference to the characteristic chalky-white color of the bark.

Pinus albicaulis was discovered in 1851 by the intrepid Scotch botanical explorer, John Jeffrey. A letter he wrote, now preserved at the Royal Gardens of Edinburgh,[1] states that he found the tree "on the summit of a mountain near Fort Hope, Fraser's River," central British Columbia, at an elevation of 7,000 feet. A. Murray,

[1] Fide Sargent, Silva, XI, 41, 1897.

a Scotch botanist, published the first account of the tree in 1853 under the name *Pinus flexilis*, confusing it with the limber pine, which was discovered and named 20 years before. Likewise, in 1857, Dr. Newberry erroneously referred to it as *Pinus cembroides*. It remained for Dr. George Engelmann to describe this pine technically and to establish its present name, *Pinus albicaulis*, in 1863. The French botanist Carrière named it *Pinus shasta* in 1867, while as late as 1880 Dr. Engelmann, then concluding that it was a closely related form of the limber pine, renamed it *Pinus flexilis* var. *albicaulis*. As now known, however, the white-bark pine is specifically distinct from our other white pines.[1]

DISTINGUISHING CHARACTERISTICS.

White-bark pine has a low, long-branched, twisted, or crooked trunk from 15 to 50 feet high and from 10 to 24 inches in diameter. Taller and larger trees occur in protected situations. In the higher wind-swept places it is often reduced to a sprawling shrub with enormous branches spreading over the ground. Young trees have distant, regular whorls of branches which stand out at right angles to the trunk, but in later life some of the upper whorls of branches develop upward into long, willowy stems, giving the tree a loose, bushy crown. The branches, especially near the trunk, are exceedingly tough and flexible, so that the tree is able to withstand the fiercest storms without being broken.

The bark, even of old trees, is little broken, except near the base of the trunk, where it is rarely more than one-half of an inch thick. Here narrow cracks divide the bark into very thin whitish or brownish scales, which when torn off reveal the characteristic red-brown inner bark. Elsewhere the bark is rarely more than one-fourth of an inch thick. Twigs of a year's and sometimes of two years' growth are slightly downy.

The dark yellow-green leaves (Pl. VI), densely clustered at the ends of the branches, are borne in bundles of 5, and are from about $1\frac{1}{2}$ to $2\frac{3}{4}$ inches long. Shorter leaves occur on trees in the most exposed situations (Pl. VI, *d*). The margins of the leaves are commonly smooth, but sometimes they have very widely separated minute teeth. A cross section of the leaf shows two resin ducts (centrally located on the dorsal or back side of leaf); occasionally a third resin duct occurs on one of the lower sides. The leaves of each season's

[1] White-bark pine was probably first introduced into cultivation in Scotland through the seeds John Jeffrey is said to have sent there from Mount Shasta, California, in 1852 (fide Elwes and Henry, op. cit., 1049). Elwes and Henry state that no plants appear to have survived, and that the only specimens now known (1910) are seedlings growing in Kew Gardens. It is probable that, like the limber pine of similar habitat, the white-bark pine can not be successfully grown in eastern United States. However, it is in no way attractive as an ornamental tree.

growth remain on the tree for approximately 7 or 8 years, but some of them for only 4 or 5 years. The cones (Pl. VI, *a*, *b*) mature by the end of August or early in September of the second year. At this time they are a deep purple. They have very thick scales, and vary in length from about 1⅓ to nearly 3½ inches. Rarely, if ever, do the cone scales become separated sufficiently to liberate the nutlike seeds (Pl. VI, *c*). As a rule, while the cones are still on the trees, and long before they are ready to fall, practically the entire crop of seeds is devoured by mountain squirrels and such birds as Clark's crow. The birds get the seeds by tearing away the cone scales; squirrels very cleverly extract all of the seeds by cutting a hole in one side of the cone (Pl. VI, *a*). The few cones that remain unopened on the trees and finally reach the ground gradually become loosened and broken by decay; then the seeds fall out or germinate in the rotted remains of the cones. The seeds (Pl. VI, *c*), about half an inch in length by one-third of an inch in diameter, have very narrow wings, which remain attached to the cone scales when the seeds fall out or are extracted; the thick, hard shell of the seeds is dark chocolate-brown. The seed-leaves of this species vary in number from 7 to 9.

The wood of the white-bark pine is rather soft, but firm in texture, and when dry very brittle. It has only a thin layer of whitish sapwood. The heartwood is pale brown when freshly cut. Owing to the exceedingly slow growth of the tree, the wood is very narrow-ringed. A cubic foot of dry wood weighs approximately 26 pounds. Prospectors occasionally use logs from this tree for cabins, for timbering "prospect holes," and for fuel.

OCCURRENCE AND HABITS.

Pinus albicaulis is confined to rather narrow altitudinal limits on alpine slopes and exposed ridges at elevations between 5,000 and 12,000 feet (Map No. 3). It grows among broken bare rocks, in disintegrated granite, and in shallow rocky soils with little superficial moisture, the best growth, however, being in well-drained, moist soil.

White-bark pine sometimes occurs in pure open stands on grassy areas, but usually in open, parklike growth, preferably on north slopes with alpine fir, Engelmann spruce, Lyall larch, limber pine, and lodgepole pine. Perhaps its most characteristic occurrence is in scattered clusters of from three to seven trees, which appear to grow as from the same root.

Pinus albicaulis is somewhat intolerant of shade in youth, becoming still less tolerant with age. It appears to be more intolerant in the North than in the South. In the South it shows a preference for north slopes. Greater tolerance of shade is shown on good moist soils at low altitudes than on poor dry ones near timber line.

In general white-bark pine is a good seeder, but seed production varies greatly with the region and locality. In the North it seeds only at long intervals, while in the South it bears seed frequently. Reproduction is rather scanty, this doubtless being due in part to the large quantities of seed eaten by birds and squirrels. Because the seeds are carried to the ground in the heavy unopened cones, reproduction is confined mainly to the vicinity of seed trees. Being unprotected by the mother trees, seedlings that come up in exposed places are often damaged by winds, which whip the stems about so that they are sometimes worn in two at the collar by rubbing against the rough granite soil.

LONGEVITY.

White-bark pine is moderately long-lived, attaining an age of from 250 years (when it may be about 19 inches in diameter) to 325 years. Very few records of the tree's longevity are available.

MEXICAN WHITE PINE.

Pinus strobiformis Engelmann.

COMMON NAME AND EARLY HISTORY.

This little-known species is without a distinctive common name, being known only as "white pine." The name "Mexican white pine" is suggested because the greater part of the tree's range is in Mexico, its range in the United States being very limited (Map No. 4).

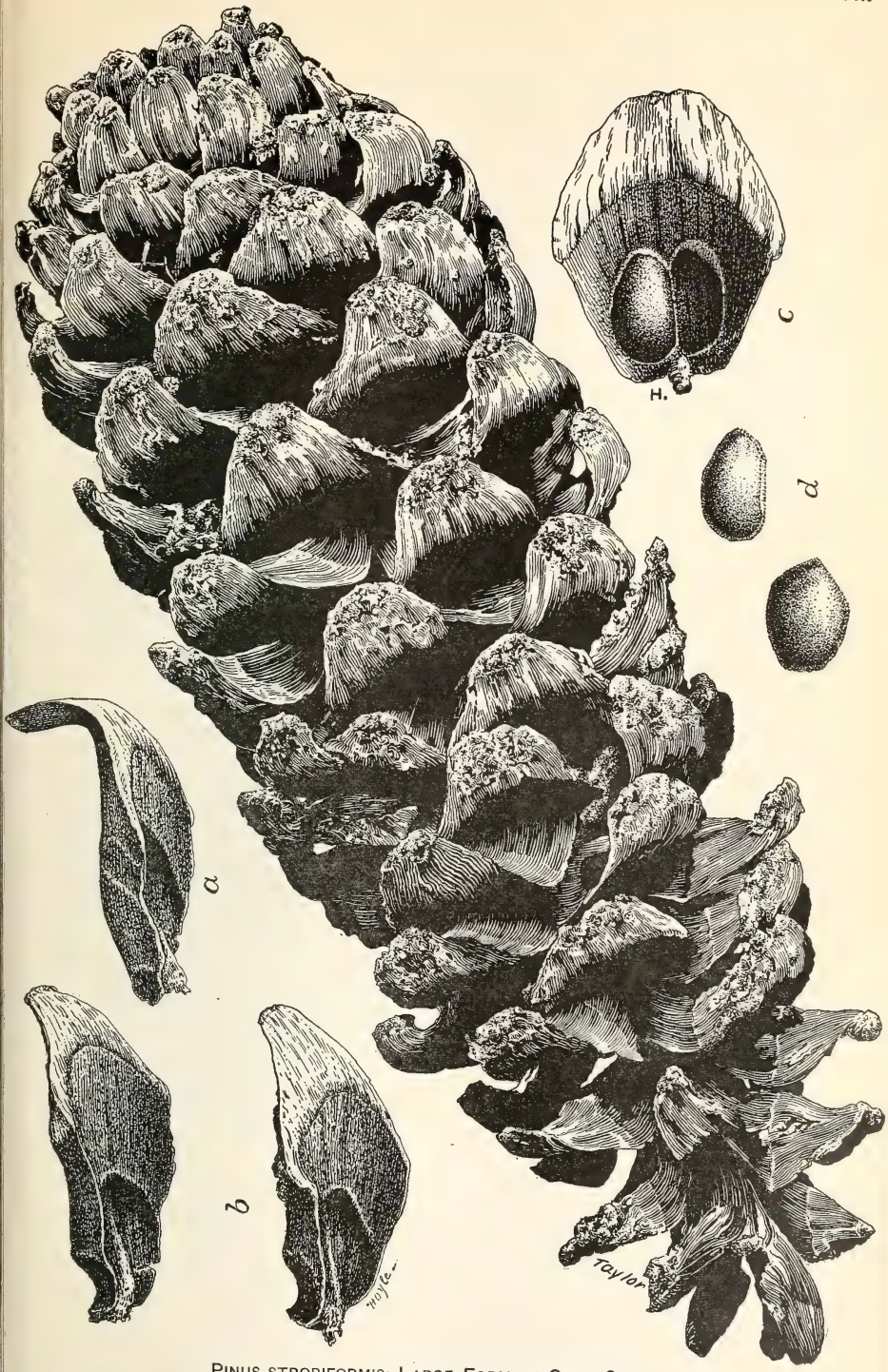
Mexican white pine was discovered in Chihuahua, Mexico, in 1846 by Dr. A. Wislizenus. Twenty-six years after its discovery in Mexico Dr. J. T. Rothrock found it in the Santa Rita Mountains, Arizona. The first description and the technical name of it were published in 1848. The botanical history of Mexican white pine shows that the tree was little understood until about 25 years ago. In 1868 a French author referred to it as *Pinus ayacahuite*, which is another Mexican species; in 1878 Dr. Engelmann named a form of it *Pinus flexilis*, γ *reflexa*, which four years later (1882) he ranked as a distinct species, *Pinus reflexa*. Under this name Mexican white pine was chiefly known to American botanists until 1889, when Prof. C. S. Sargent[1] pointed out that Engelmann's *Pinus reflexa* and *P. strobiformis* refer to the same tree, the latter name being the older.

Recently Dr. G. R. Shaw[2] reduced this species to "*P. ayacahuite* var. *brachyptera* Shaw." For the present, however, the writer prefers to

[1] Gard. and For. II, 496, 1889. [2] The Pines of Mexico, Pl. vi, p. 11, 1909.

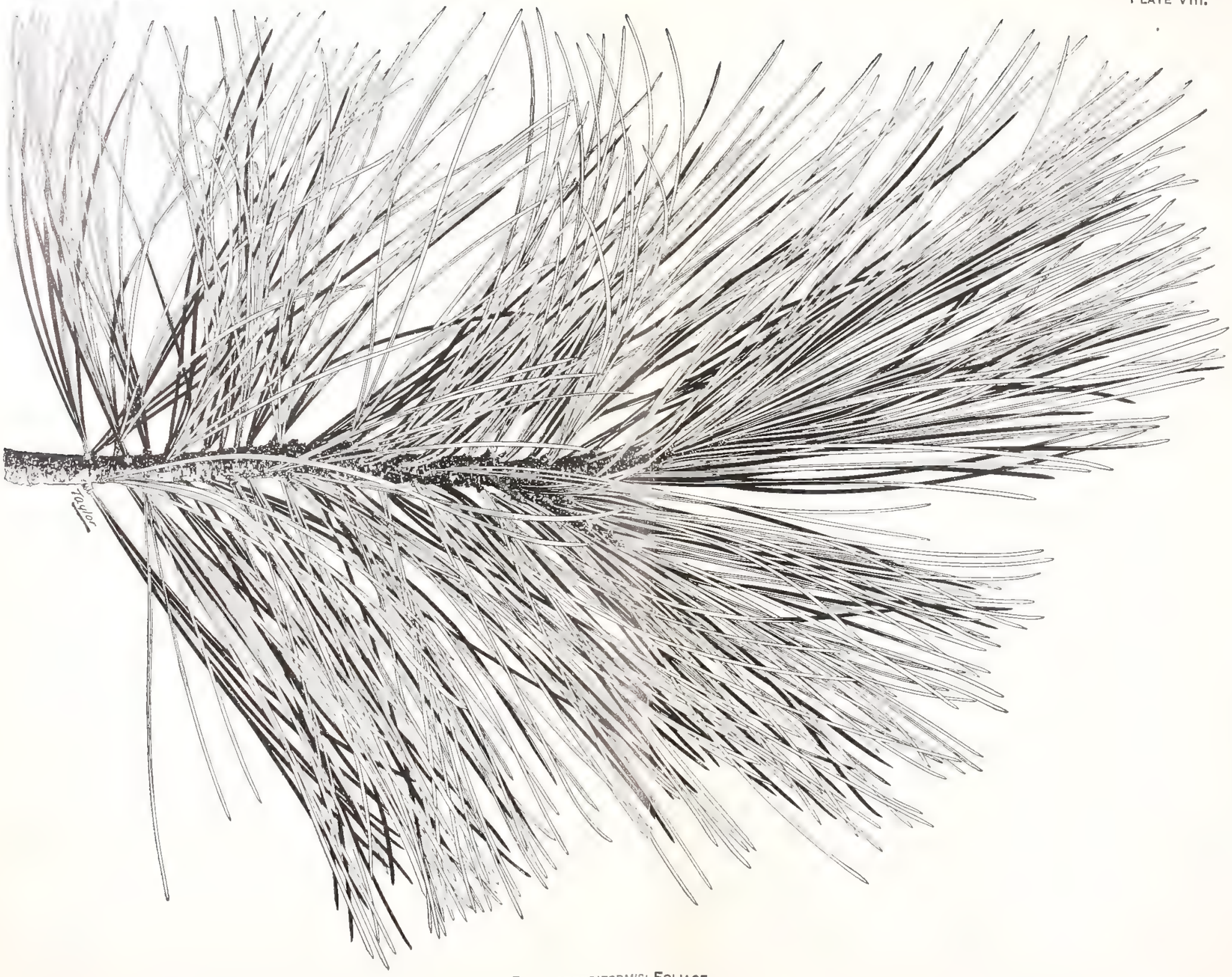
PINUS ALBICAULIS: FOLIAGE AND CONES.

a, Detached cone, from which a squirrel has cut out the seeds; *b*, detached cone; *c*, seeds; *d*, detached leaf bundles, showing variation in length.

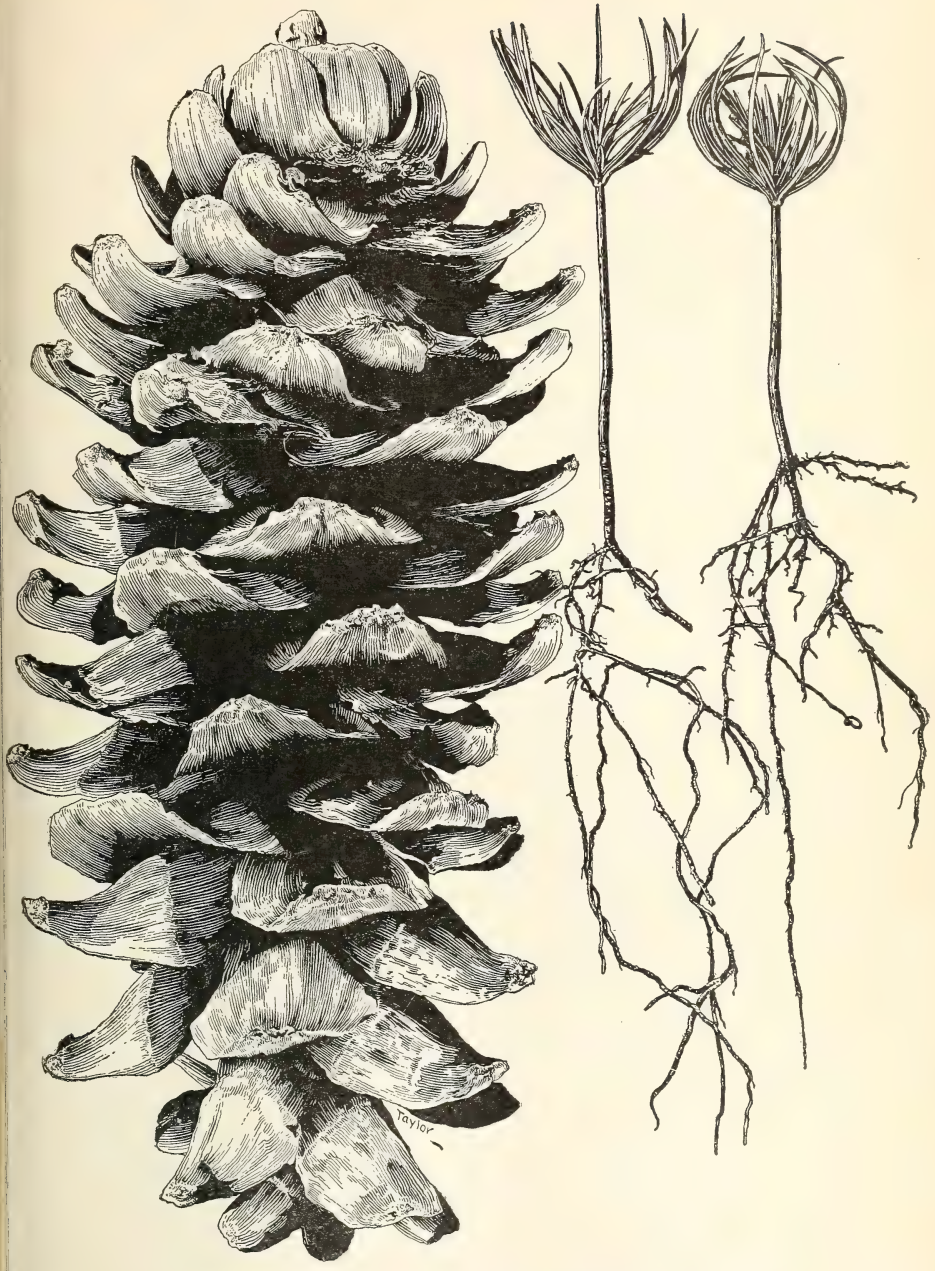


PINUS STROBIFORMIS: LARGE FORM OF OPEN CONE.

a, *b*, Different forms of cone scales (upper side); *c*, upper side of cone scale with its seed; *d*, seeds.

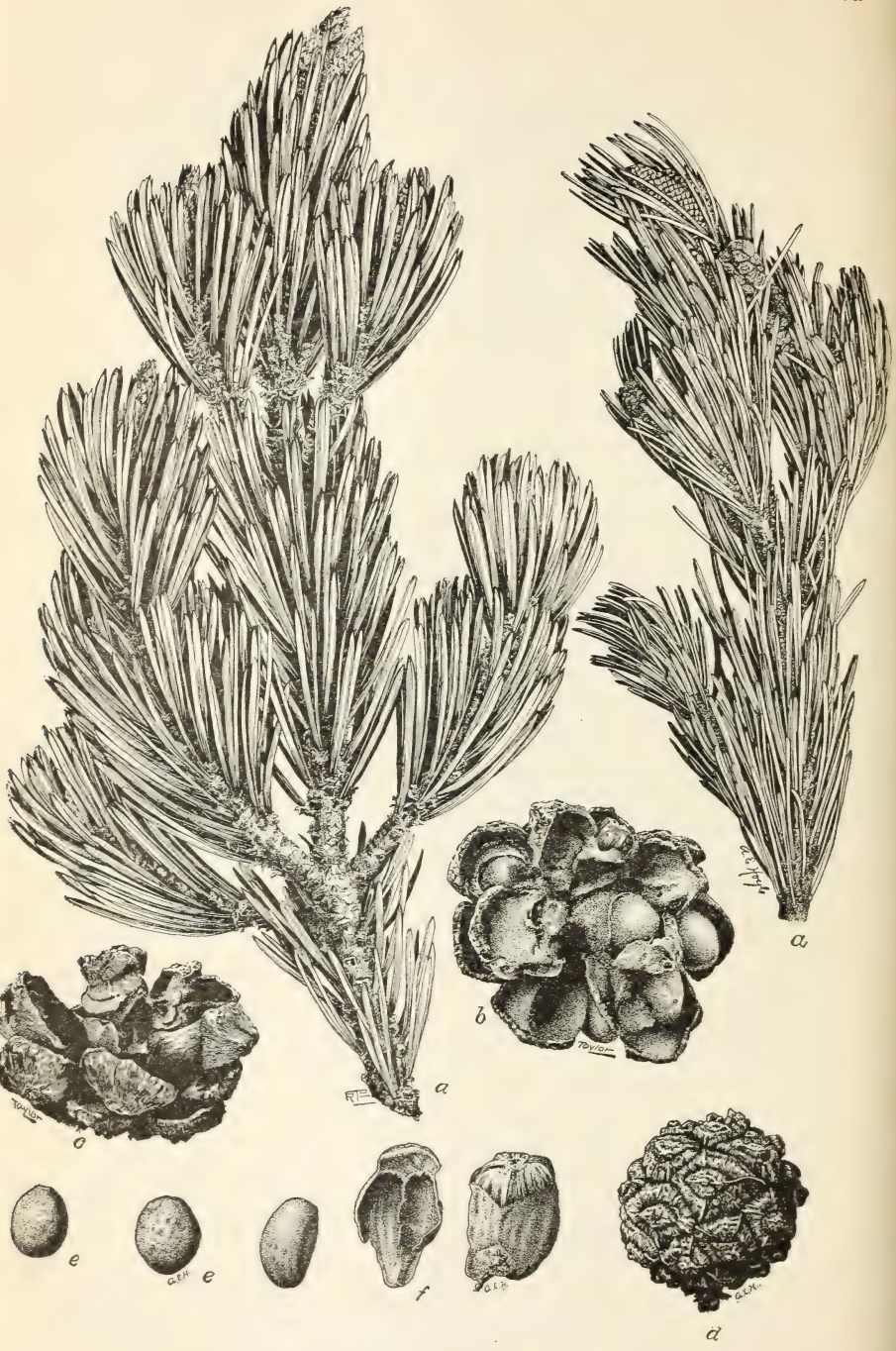


PINUS STROBIFORMIS: FOLIAGE.



PINUS STROBIFORMIS: OPEN CONE. (NATURAL SIZE.)

a, Seedlings about two months old (two-thirds natural size).



PINUS CEMBROIDES.

a, Foliage; *b*, top view of open cone with seeds; *c*, side view of open cone; *d*, ripe closed cone; *e*, seeds; *f*, cone scales, showing upper and lower sides.

maintain it as a species and to retain for it Engelmann's original name, *P. strobiformis*. While the cone scales of *P. ayacahuite* Ehrenberg and *P. ayacahuite veitchii* Shaw, wholly Mexican pines, resemble those of *P. strobiformis* Engelm., the seed wings of the first two pines are well defined and from two to three times as long as the seeds, while the seed wing of *P. strobiformis* is very rudimentary, being scarcely one-eighth of an inch long.[1]

DISTINGUISHING CHARACTERISTICS.

The longer-leafed forms of this tree, grown in protected places at low elevations, have somewhat the aspect of the eastern white pine (*Pinus strobus*), while the shorter-leafed trees, found in exposed higher situations, have a general resemblance to the limber pine (*Pinus flexilis*). Mexican white pine usually has a narrow conical crown with drooping branches, especially the lower ones, and a rather short, clear, straight, often rapidly tapering trunk. In favorable situations, and when they have reached their full growth, the trees are from 60 to nearly 100 feet high and from 16 to 20 inches in diameter, or exceptionally from 28 to 36 inches in diameter. Commonly, however, the height is from 50 to 60 feet and the diameter from 14 to 16 inches. The trunk bark, about $1\frac{1}{4}$ inches thick, is dull red-brown and rather deeply and irregularly furrowed and narrowly ridged, the main ridges being more or less connected by smaller ones and composed of small, easily detached scales. The young twigs are at first covered with reddish-brown hairs, most of which disappear during the first winter.

The pale blue-green leaves (Pl. VIII), borne in clusters of five, are slender, rather stiff, and from 3 to about 4 inches long. Leaves of each season's growth remain on the twigs for about four years; some of them, however, are shed during the third year. Retention of each season's leaves until practically the fourth year gives the crown a dense, well-clothed appearance. The margins of the leaves have minute, sharp, widely separated teeth. A cross section of the leaf shows two resin ducts (on the back of the leaf near the border). The lower or ventral sides of the leaves are marked with from 3 to 4 lines of minute pores (stomata), none being found on the back or dorsal sides of the leaves. This characteristic, first pointed out by Coulter & Rose in 1886, may serve to separate perplexing forms of this pine from its close relative *Pinus flexilis*, the leaves of which have dorsal stomata.

[1] So far as is known *Pinus strobiformis* has not been introduced into cultivation in Europe, nor has it been cultivated in eastern United States. Judging from the behavior of *Pinus flexilis* in England, to which *Pinus strobiformis* is similar in its requirements of soil and climate, the Mexican white pine also is likely to be adapted for growth in that country. The poor showing made by *Pinus flexilis* in eastern United States similarly indicates that *Pinus strobiformis* would not grow well in that region.

Mature cones are from 4¾ to 9¼ inches long (Pls. VII and IX). The most distinctive characteristic of the cone is the strongly reflexed thin tips of the cone scales. (Pl. VII, *a*, *b*.) No other pine in the United States has cones so strongly marked. The pendent cones are mature about the middle of September and usually drop their seeds by the middle of October. They fall from the trees in late autumn or early winter. At maturity the cones are light yellowish-brown, unexposed parts of the scales being dull red. The nutlike seeds are dark brown, slightly tinged with red, and are provided with a very short wing. (Pl. VII, *c*, *d*.) The seed-leaves are from 10 to 12 in number. (Pl. IX, *a*.)

The wood of Mexican white pine is moderately heavy for a white pine, a cubic foot of it when dry weighing about 30¼ pounds. It is rather hard and narrow-ringed ("fine-grained"[1]). The sapwood is thin and whitish, the heartwood being a very pale reddish-brown. In general appearance and texture lumber from this tree resembles that from old trees of the eastern white pine (*Pinus strobus*), while its "working" qualities are similar to those of western white pine (*Pinus monticola*). The limited distribution of this tree in the United States and its occurrence in places difficult of access has so far prevented any but local use of the timber, the best grades of which would readily serve as a substitute for western white pine.

OCCURRENCE AND HABITS.

Mexican white pine grows in dry, rocky, or gravelly soils on mountain slopes, canyon sides, and ridges at elevations of from about 5,500 to 9,700 feet; it is only very occasionally that straggling trees

[1] The popular conception of the "grain" of wood appears to refer mainly, if not entirely, to the thickness of the annual layers of growth. Thus woods with thin or thick layers of growth are commonly called "fine-grained" or "coarse-grained." Such other qualities of wood as compactness or density and porosity of structure are popularly described as "dense," "very dense," "compact," or as "porous" and "nonporous." In view of this evident popular confusion in reference to "grain," it is here maintained that grain should properly refer only to the structural constitution of wood within the annual or other periodic layers of growth, and not to the thickness of the annual increment, which is consistently described by such terms as "wide-ringed" and "narrow-ringed" wood. Uniform thickness of the periodic layer of growth is only exceptionally characteristic of any wood under all conditions of the tree's life, while the structural elements of different woods remain fairly constant. The characteristic structure of different woods results from the association of different individual cell-elements (fibers and vessels). These elements have distinctive forms, which vary within limits characteristic of different groups of woods, and also of the same species grown under different conditions. Wood elements are also characteristically assembled in different genera and species of woods. In one, these elements may be so associated as to form the popular and correctly termed "cross-grained" wood, as in sycamore (*Platanus*) and in gum (*Nyssa*), etc. In another, they may form "straight-grained" wood, as in white ash, white pine, etc. Again, the elements may take a wavy longitudinal course, or an abruptly-curved course, and produce the "curly-grained" and "birds-eye" wood. So also, when the elements are spirally disposed with reference to the axis of the tree, the wood has a "twisted grain." If all of the elements of a wood are small and about the same width, the structure can properly be termed "fine-grained." So, too, if many of the cell-elements are large, the wood produced is "coarse-grained."

are found at as low a level as 5,500 feet (Map No. 4). The largest and best-formed trees are found on moist, gravelly flats and canyon slopes at elevations between 7,000 and 8,000 feet. They are commonly much scattered, growing singly or occasionally in small groups, and generally associated with Arizona pine and Douglas fir at higher elevations.

This pine can endure moderate shade only during the seedling and small sapling stages of growth. After this it requires full overhead light. Older overtopped trees show greatly reduced vigor in the density of foliage and also in the rapidity of their height and diameter growth.

Mexican white pine is a moderate seeder, the amount of seed borne varying with the elevation. Seed production is greatest at the middle elevation, even the better grown trees in protected places at lower altitudes producing smaller quantities of seed. Good crops of seed are borne at intervals of about 3 years, although some seed is produced nearly every year. The nutlike practically wingless seeds fall near the trees and soon afterwards many of them are devoured by birds and squirrels. The latter also eat the seeds of a large number of the ripe closed cones, which they "cut down." This destruction of perhaps the major part of the season's crop doubtless accounts for the sparse reproduction of the species. Germination occurs most often in mineral soil held in pockets or otherwise protected from washing. In some instances mountain flood waters carry the seeds to lower levels than they would ordinarily reach, thus extending the vertical distribution of the tree to exceptionally low elevations (5,500 to 6,000 feet).

LONGEVITY.

Pinus strobiformis is a moderately long-lived tree and of fairly rapid growth. Trees from 14 to 20 inches in diameter are approximately from 80 to 110 years old, and those from 28 to 30 inches through are from 150 to 180 years old. It is probable that this pine reaches an age of 250 years or more in protected situations. Further determinations are required to fix the extreme limit of age.

MEXICAN PIÑON.

Pinus cembroides Zuccarini.

COMMON NAME AND EARLY HISTORY.

Of all of our nut pines this species is perhaps the least known to laymen. It has no distinctive common name, being called "piñon" and "nut pine." The name Mexican piñon, here used to distinguish the tree from other nut pines, would appear to be appropriate, because the species occurs almost wholly in Mexico (Map No. 5).

Pinus cembroides was discovered[1] about 1830 by the Belgian explorer Karwinsky in the southern part of the State of Mexico.[2] It remained unknown in the United States until 1882, when it was found on the Santa Catalina Mountains, Arizona, by Mr. C. G. Pringle,[3] an American botanist and explorer. *Pinus cembroides*, the first technical name applied to the Mexican piñon, was published in 1832.[4]

DISTINGUISHING CHARACTERISTICS.

Mexican piñon is ordinarily a very short-trunked tree from 12 to 25 feet high and from 7 to 12 inches in diameter. Such trees have a clear trunk of from 3 to 8 feet. Trees growing in protected places reach a height of from 35 to 50 or more feet, with 15 to 18 feet of clear trunk and a diameter of from 12 to 14 inches. The crowns of young trees are compact and conical, the branches being more or less upright; the crowns of old trees are wide and rounded, the lateral crown branches being mostly horizontal. On large trunks the bark is pale reddish brown, distinctly scaly, thin (not over half of an inch thick), and divided by very shallow furrows and ridges, which are not connected by smaller side ridges as in the case of other nut pines.

The foliage, especially on young trees, is a deep bluish green, that of each season's growth remaining on the branches about 4 years, though most of it falls during the third or fourth season. The number of leaves borne in a bundle is commonly 2 or 3 (rarely and exceptionally 1, 4, and 5). They are from about 1 to 2 inches long, acutely pointed, strongly incurved, and smooth on the margins. A

[1] Fide Sargent, Silva, XI, 48, 1897.

[2] According to Elwes and Henry (The Trees of Great Britain and Ireland, V, 1059, 1910) *Pinus cembroides* was introduced into England in 1830. (If this date be correct, it is probable that Karwinsky, the discoverer of the tree, found it in Mexico at an earlier date than "about 1830," the year indicated by Prof. Sargent, l. c.). They state that in 1908 trees of this species planted in England reached a height of 25 to 33 feet. It is said to have been introduced into Europe by Hartweg in 1846 (fide Sargent, l. c.) and is now cultivated for ornament in southern Europe.

[3] Sargent, l. c.

[4] Since the first publication of this tree as a species in 1832 botanists have generally held it to be distinct from the other southwestern nut pines, the only names applied to it, until quite recently, being *P. llaveana* Schl. and *P. osteoperma* Engelm., now relegated to synonymy. In 1907, however, a German botanist (Voss, Mitt. Deutsch. Dend. Fresell., XVI, 95, 1907) pronounced it to be related to the single-leaf pine and the two-leaf piñon, which he designates as *P. cembroides* var. *monophylla* and *P. cembroides* var. *edulis*, to which he has also added our southern California four-leaf pine (*P. parryana*) as *P. cembroides* var. *parryana*. This writer considers the cones of all of these piñons essentially alike; and, owing also to the inconstancy in the number of leaves borne by each, he is unable to separate them satisfactorily as species. The present writer, however, prefers to maintain the Mexican piñon as a distinct species: (1) because, in the main, our forms of the tree have a reasonably constant number of leaves in each fascicle; (2) because the cones are distinguishable in size and other characteristics, the seeds also having the same general distinctions; (3) because the bark is distinctly scaly and only slightly ridged, that of the other nut pines being markedly ridged; (4) because the number of seed-leaves is greater than in any other nut pine; (5) and, lastly, because the wood has characteristics which distinguish it.

cross section of the leaf shows two resin ducts (near the border on the back of leaf).

The cones ripen during September and drop their seeds[1] by the middle or latter part of October. Only the scales in the middle of the cones bear perfect seeds. Externally, the cones are pale yellowish or reddish brown. The empty cones fall from the trees mostly in late autumn and early winter. Mature cones (Pl. X, *b*, *c*) which are globelike or egg-shaped and borne on very short stems, vary in length from about 1 inch to 2½ inches, and in breadth from about 1 inch to nearly 2¾ inches. The seeds (Pl. X, *e*) are from one-half to three-fourths of an inch long by about one-fourth to three-eighths of an inch wide. They vary in color from light yellowish brown to a deep chocolate-brown on the under surface (which is always darker) to cinnamon-brown on the upper side. The pale cinnamon brown wings of the seeds are extremely short (rudimentary) and remain attached to the scales when the seeds fall (Pl. X, *b*, *c*, *f*). Seed-leaves are from 9 (occasionally 8) to 15 in number.

The wood of *Pinus cembroides* is very narrow-ringed, and moderately soft, but firm. It is the heaviest of all the Rocky Mountain pines, a cubic foot of dry wood weighing about 40½ pounds. In this country the wood is used locally only for fuel and for other minor domestic purposes.

OCCURRENCE AND HABITS.

Pinus cembroides grows in poor, shallow, rocky, and gravelly soils on hot mountain slopes, precipitous canyon sides, benches, and foothills at elevations between 4,800 and 7,500 feet (map No. 5). Within our border it forms scattered growths, interspersed here and there with *Quercus reticulata*, *Q. hypoleuca*, and *Q. arizonica*. In its more extensive range in Mexico it sometimes occurs in practically pure, but rather open stands.

The light requirements of this species are insufficiently known at present; but it appears to be intolerant of shade, except during early youth, and even at that time it endures only partial shade.

Seed production occurs usually every other year, but heavy crops of seed are borne only at intervals of three or four years. Trees begin to bear cones comparatively early, seed production increasing steadily to old age. A large percentage of the seeds are sound, but their vitality is very transient, so that, except under specially favorable conditions for germination, reproduction occurs sparingly. Seedlings are generally much scattered, and mainly on washed mineral soil. Sparse reproduction where the tree occurs abundantly is prob-

[1] The seeds are extensively gathered for food in Mexico; but in the United States few are obtained for this purpose because of the limited occurrence of the tree.

ably due, in large measure, to the fact that quantities of the seed are collected for food and for sale as sweetmeats, while in localities where this pine is less abundant rodents and birds devour much of every crop, for shortly after the seeds have fallen it is often difficult to find a single perfect one.

LONGEVITY.

The extreme age limit of Mexican piñon has not been determined. It grows very slowly throughout its life, attaining an age of possibly 225 years. Trees from 7 to 10 inches in diameter are from 125 to 185 years old.

PIÑON; NUT PINE.

Pinus edulis Engelmann.

COMMON NAME AND EARLY HISTORY.

This distinctly desert-foothill tree is rarely if ever distinguished by lay people from the single-leaf pine (*Pinus monophylla*), especially where the two species are mingled. Sometimes the long-leafed and larger-coned forms of *Pinus monophylla* and the shorter-leafed, smaller-coned forms of *P. edulis* are spoken of as different "varieties" of the piñon tree that yields the "pine nuts" which Indians and settlers gather for food.

The history of the piñon is closely connected with that of the single-leaf pine and shows that there has been much difference of judgment, which obtains even at the present time, regarding their botanical relationship, particularly their claims to specific rank. Single-leaf pine was found for the first time by Gen. John Charles Frémont in 1844 in southern California and was described in 1845 as a distinct species under the technical name *Pinus monophylla* Torrey. Similarly, the piñon, found first by Dr. Wislizenus in New Mexico in 1846, was botanically described in 1848 for the first time as a distinct species under the name *Pinus edulis* Engelmann.[1] Forty-three years after this (1891) the latter tree was reduced to a variety of the single-leaf pine and designated as *P. monophylla* var. *edulis* M. E. Jones, while 16 years later (1907) it was again described as *P. cembroides* var. *edulis* Voss.[2] Writers have differed also as to the proper botanical rank of the single-leaf pine; for in 1860, 15

[1] It is not definitely known when *Pinus edulis* was first cultivated in England or in European gardens, where it is said to be growing. Elwes and Henry (Trees of Great Britain and Ireland, V, 1058, 1910) state that small plants of it are growing in Kew Gardens. Prof. Sargent (Silva, XI, 57, 1897), says that it is hardy in eastern United States as far north as eastern Massachusetts. In 1886 the writer saw a small tree of this species, planted by William Saunders in the grounds of the Department of Agriculture about 1870. It died in 1888 after reaching a height of about 5 feet, apparently not being adapted to the soil and climatic conditions at Washington, where its growth had been exceedingly slow.

[2] See footnote 4, page 16.

years after it was first described as a distinct species (*P. monophylla* Torrey), it was reduced to the rank of a variety (*P. edulis* var. *monophylla* Torrey); and 47 years later (1907) it, too, was designated as *P. cembroides* var. *monophylla* Voss,[1] a judgment in which at least one author has concurred as late as 1909.

The present writer prefers, however, to consider the piñon and single-leaf pine as distinct species. For this opinion there is good ground in the microscopic structure and external form of the leaves of both trees, as well as in the size of their cones. Perplexing and anomalous leaf forms of both trees occur, particularly where the ranges of the two trees come together. Thus it is possible to find individual trees in southern Utah bearing one-leafed and two-leafed fascicles, but these must be considered *P. edulis*, because the apparently monophyllous fascicles can usually be shown to be structurally two-leafed. So also anomalous two-leafed fascicles of trees bearing mostly single leaves will generally have the essential anatomical structure of *P. monophylla*, to which such exceptional trees must be referred.[2] It should be noted in this connection that similar variations from the usual number of leaves borne are peculiar also to other western and eastern pines. In the case of these species, however, such variations have not yet been considered sufficient ground for uniting them as varieties.

DISTINGUISHING CHARACTERISTICS.

The piñon has a short, often crooked, trunk, which gives off several large, crooked branches and is rarely clear of limbs for more than 15 feet, and usually for only 6 or 8 feet. Young trees have broad cone-shaped crowns, but when the trees have become full grown the crown is spherical or occasionally somewhat flat-topped. The height attained varies from 10 to 35 feet or more, but commonly it is from 12 to 16 feet, with a diameter of from 12 to 30 inches. The irregularly developed, leaning, crooked trunks and low-hanging branches of this pine give it the general appearance of an old apple tree. The bark of mature trunks is shallowly and irregularly furrowed, the main ridges being joined by diagonally disposed smaller ridges. Both the main ridges and the smaller ones are broken into small, close, detachable scales. Superficially the bark has a tint of yellowish or reddish brown. It varies in thickness from about one-half to seven-eighths of an inch.

[1] See footnote 4, page 16.

[2] How far we have in the anomalous forms of these two piñons evidences of the derivation of a one-leafed species from the probably more ancient two-leafed tree it is impossible to say at present. The somewhat more arid habitat, in part, of the one-leafed tree would seem to support belief that the one-leaf form of foliage is the direct result of a psysiological necessity—a leaf of such simple character as would permit the tree more easily to maintain itself under arid conditions.

The foliage of adult trees is a dark yellowish green, while that of seedlings is a bright bluish green. Each season's growth of leaves remains on the branches for nearly 9 years, though a good many leaves fall during the fourth summer. The leaves are borne in clusters of 2, occasionally of 3 (Pls. XI, XII). They are sharp pointed, often curved, and vary in length from about seven-eighths of an inch to nearly $1\frac{3}{4}$ inches. The margins of the leaves are smooth (without minute teeth). In cross section the leaves show two resin ducts.

The yellowish-brown and somewhat shiny cones (Pl. XI) are from about $1\frac{1}{4}$ to nearly $1\frac{3}{4}$ inches long. They ripen in August and September and shed their nutlike edible seeds (Pl. XI, *b*) during the latter part of September and in October, the very short rudimentary wings (from one-eighth to one-sixth of an inch long) remaining attached to the cone scales (Pl. XI, *a*) when the seeds fall. Unexposed parts of the cone scales are pale red-brown. The perfect seeds,[1] borne only by scales in the middle of the cone, are pale yellow with reddish-brown specks and mottlings on one side and dull red-brown on the other. Most of the empty cones fall from the trees during the first winter or early the following spring. The seed-leaves (Pl. XII, *a*, *b*) vary in number from 7 to 10.

The wood of *Pinus edulis* is narrow-ringed and hard, but very brittle. The thin layer of sapwood is nearly white, and the heartwood is light yellowish brown. Next to that of *Pinus cembroides* it is the heaviest of Rocky Mountain pine woods, a cubic foot of dry wood weighing nearly 40 pounds. It is used largely for fuel, ties, fence posts, and other local purposes.

OCCURRENCE AND HABITS.

Pinus edulis grows on dry foothills, mesas, mountain slopes, and sides of canyons, at elevations between 5,000 and 9,000 feet, or occasionally somewhat below 5,000 feet (Map No. 6). It is usually found in poor, rocky, gravelly soils, but often in shallow or deep layers of gravel and sand overlying rock, and sometimes in the crevices of rocks. Very commonly, it is associated with western yellow pine, one-seed juniper, Utah juniper, mountain mahoganies, Gambel oak, and mountain red cedar. Its most frequent associates are, however, the one-seed and Utah junipers. Occasionally it forms pure stands of limited extent. The largest growths occur on mesas and elsewhere at the lower elevations noted, where the sandy or gravelly soil deposited by washing is moderately rich.

Piñon is very intolerant of shade in all but the seedling stages of its growth, a period when partial shade assists the young plants to

[1] Indians and settlers gather large quantities of the seeds; the former use them largely for food, and the latter send them to eastern and other city markets as sweetmeats. Birds and squirrels and other rodents, however, claim a large share of piñon seeds, many of which are devoured before the cones open.

PINUS EDULIS: FOLIAGE AND OPEN CONES.

a, Upper and lower sides of cone scales; *b*, seeds.

PINUS EDULIS: FOLIAGE.

a, Seedlings one month old (natural size); *b*, seedlings six months old (one-third natural size).

PINUS MONOPHYLLA: FOLI

a

PINUS MONOPHYLLA: FOLIAGE.

a, *b*, Open cones; *c*, upper side of cone scale with its seeds.

AGE AND OPEN CONE (ATTACHED TOP VIEW).

Detached closed cone.

become better established than in the full sunlight. Piñon bears seed very abundantly about every 2 years, but sometimes only at intervals of 3 years. The wingless nutlike seeds always fall beneath or near the trees. When fruiting trees occur on slopes, the seeds may be washed some distance away and sometimes into depressions and crevices where, when buried in soil or débris, they have the most favorable opportunity for germination. Very few seeds that are left on top of the ground germinate. As a rule, therefore, reproduction is very sparse and much scattered, never dense. Scanty reproduction is, however, doubtless due also to the fact that so large a part of each seed crop is devoured by birds or mammals and gathered by settlers and Indians.

LONGEVITY.

Piñon is a very slow-growing tree, attaining an age of from 150 to 375 years or more.

SINGLE-LEAF PINE.

Pinus monophylla Torrey and Frémont.

COMMON NAME AND EARLY HISTORY.

This species is unique among all North American pines in having single leaves. Generally it is known only as "nut pine" or "piñon." It is desirable, therefore, in order popularly to distinguish this tree from other nut pines, to adopt "single-leaf pine" as its common name.

Pinus monophylla was discovered in 1844 in Cajon Pass, San Bernardino County, southwestern California, by Gen. John C. Frémont, while on his expedition through Oregon and California.[1] The first technical name applied to it, *Pinus monophylla* Torrey, was published in 1845. Two years later (1847) the German botanist Endlicher described and named it "*Pinus fremontiana*," and in 1860 Dr. Torrey designated it as *Pinus edulis* var. *monophylla*. The last name applied to it is *Pinus cembroides* var. *monophylla* Voss.[2]

DISTINGUISHING CHARACTERISTICS.

Single-leaf pine is characteristically a low, sprawling tree. Mature trees have short trunks, which are rarely straight, and wide, rather

[1] *Pinus monophylla* was introduced into cultivation in Europe in 1848, where, according to Elwes and Henry (The Trees of Great Britain and Ireland, V, 1057, 1910) some specimens of it appear to have grown very slowly, although a few trees have grown more rapidly and are healthy. The largest trees found by Elwes and Henry (l. c.) were from 13 to 20 feet high between 1908 and 1910. Single-leaf pine is occasionally cultivated in eastern United States, where it is hardy as far north as eastern Massachusetts (Sargent, Silva, XI, 53, 1897). Its growth there is, however, exceedingly slow. Like the piñon, this pine is not attractive for ornamental planting.

[2] See footnote 4, page 16.

Pinus monophylla: Foliage and Open Cone (Attached Top View).

a, Detached closed cone.

flat crowns of short, heavy, twisted, and bent branches. The latter grow from near the ground and often hang low, giving the appearance of an old apple tree. Young trees are very different in appearance because their low, thick trunks, have pyramidal crowns of rather straight, ascending branches. As a rule, the single-leaf pine does not exceed 25 feet in height and from 12 to 15 inches in diameter. In protected and otherwise favorable situations it may, however, reach a height of from 35 to 50 feet. The bark of young trees is smooth and dull gray, while that of old trees is roughly and irregularly furrowed, nearly an inch thick, and with thin, close, dark brown, or sometimes reddish brown scales. The general color of the foliage is pale yellow green, with a whitish tinge. The single (or very occasionally double) leaves are stiff, curved toward the branch, prickly, and from about $1\frac{1}{3}$ to $2\frac{1}{4}$ inches long; generally they are about $1\frac{1}{2}$ inches long (Pls. XIII, XIV). Each season's growth of leaves remains on the tree about 5 years; not infrequently, though, leaves persist for 10 or 12 years. A striking peculiarity of seedling trees is that they continue to produce only primary leaves for 6 or 7 years, after which they put forth the adult form of foliage.

The cones (Pls. XIII, *a*, *b*, and XIV, *a*) are matured in August of the second season, and the tips of the scales are then shiny and a deep russet-brown. The seeds fall within about a month afterwards. Most of the empty cones (Pl. XIV) fall from the trees during the winter or spring. The seeds (Pl. XIII, *c*) are dark chocolate-brown with dull yellowish areas. The pale brown seed wings, ragged and irregular, are from one-fourth to one-half of an inch long and remain attached to the cone scales (Pl. XIII, *c*—the torn border at inner ends of seeds). Seed-leaves of this pine range from 7 to 10 in number.

The wood of single-leaf pine is very narrow-ringed, exceedingly brittle, and rather soft. It usually has a thick layer of whitish sapwood, the heartwood being a pale yellowish brown. A cubic foot of dry wood weighs about $35\frac{1}{4}$ pounds. Settlers use large quantities of the wood for fuel and temporary fence posts, and a good many small towns within reach of the timber derive their principal supply of fuel from it.

OCCURRENCE AND HABITS.

Single-leaf pine occurs on low arid mountain slopes, canyon sides, foothills, and mesas, commonly at elevations between 2,000 and 7,000 feet, or less frequently up to 9,000 feet (map No. 7). Its requirements of soil moisture and quality of soil are closely similar to those of its frequent associates, the junipers, piñon, and chaparral, but less

than in the case of other conifers in its general range. Single-leaf pine occurs commonly in coarse, gravelly soils, shallow deposits overlying granite, limestone, or shale and often in the crevices of rocks. It frequently forms pure, open stands over large areas, but usually it is associated with other trees, such as mountain mahogany, Utah juniper, mountain red cedar, oaks, tree yuccas, and occasionally with piñon. The largest trees and the pure stands occur mainly at the lower and middle levels of the tree's vertical range.

Pinus monophylla is very intolerant of shade throughout life. Seedlings grow faster, however, for several years under partial or light shade and also when protected from hot winds.

This species bears some seed nearly every year and abundantly at intervals of two or three years. As in the case of other nut pines, the wingless seeds fall near the tree, whence they are sometimes disseminated by flood waters. Birds and squirrels eat large quantities of them and Indians and whites collect them extensively for food. Exposed loose soil is the best seed bed, though even here germination occurs sparingly, so that reproduction is very scattered.

LONGEVITY.

Pinus monophylla is an exceedingly slow growing tree, reaching an age of from 100 to 225 years. Trees in thin, dry soil are especially slow in their growth, specimens from 4 to 6 inches in diameter being from 80 to 100 years old. Trees occurring in deeper soils grow more rapidly, those from 10 to 12 inches in diameter being from 150 to 160 years old. Further records are required to establish its extreme age limit.

BRISTLE-CONE PINE.

Pinus aristata Engelmann.

COMMON NAME AND EARLY HISTORY.

Bristle-cone pine is known to people in and near its high mountain habitat chiefly as "fox-tail pine," because of the close resemblance of its foliage to that of the true fox-tail pine (*Pinus balfouriana*), a California species. It is sometimes known also as "hickory pine." An appropriate and distinctive name is bristle-cone pine, which is derived from the tree's specific name, *aristata* (bearded), referring to the bristlelike prickles of the cone scales.

It is probable that the earliest discovery of this pine was made in 1853 by Capt. J. W. Gunnison, of the U. S. Army, who collected a coneless branch in Cochetopa Pass (nearly southwest of Pikes Peak), Colorado, which Dr. Engelmann[1] believed to be of this

[1] Trans. St. Louis Acad. Sci., II, 205. 1863.

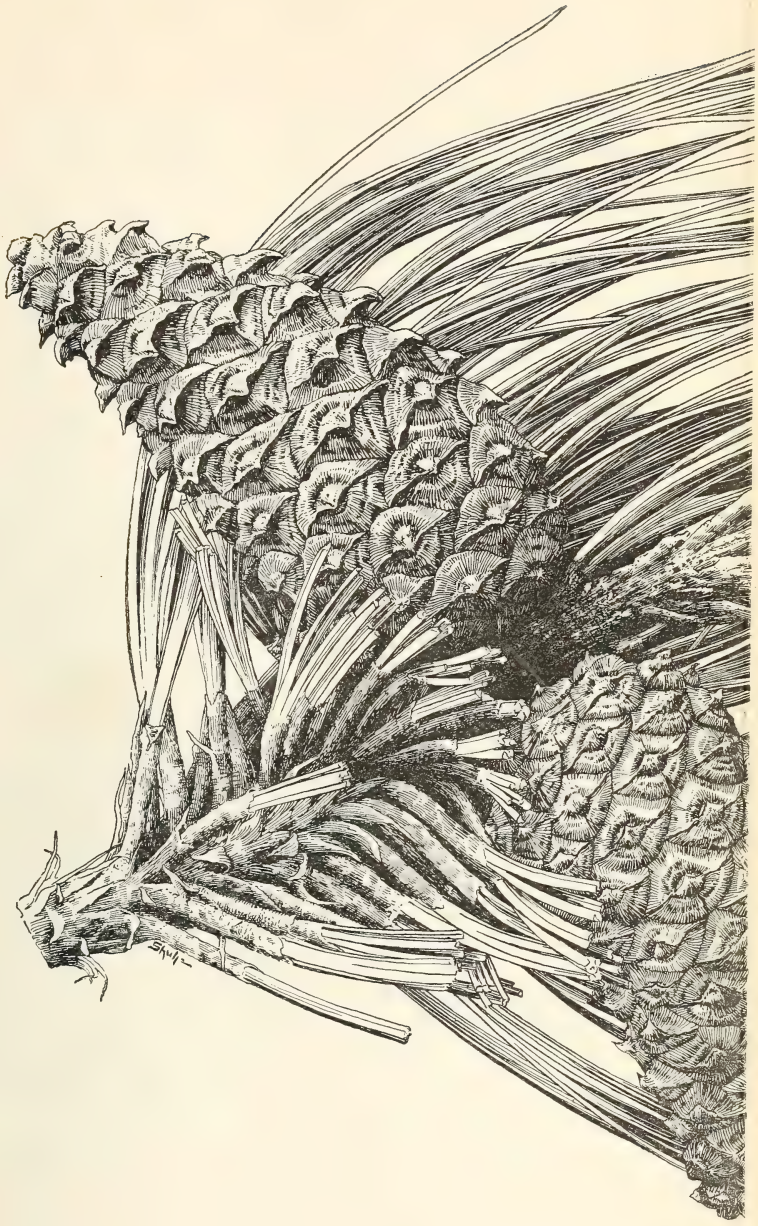
species. So keen an observer as Dr. Engelmann could hardly have mistaken the foliage of any other Rocky Mountain pine for that of *Pinus aristata*. The first authentic specimens of the tree were, however, collected by Dr. C. C. Parry on Pikes Peak, Colorado, in 1861. Bristle-cone pine received its present technical name, *Pinus aristata*, in 1862, since which date the history of the tree has been practically free from confusion. In 1878 it was designated as *P. balfouriana* var. *aristata* Engelm., but this suggested relationship to the California species is not generally accepted.[2]

DISTINGUISHING CHARACTERISTICS.

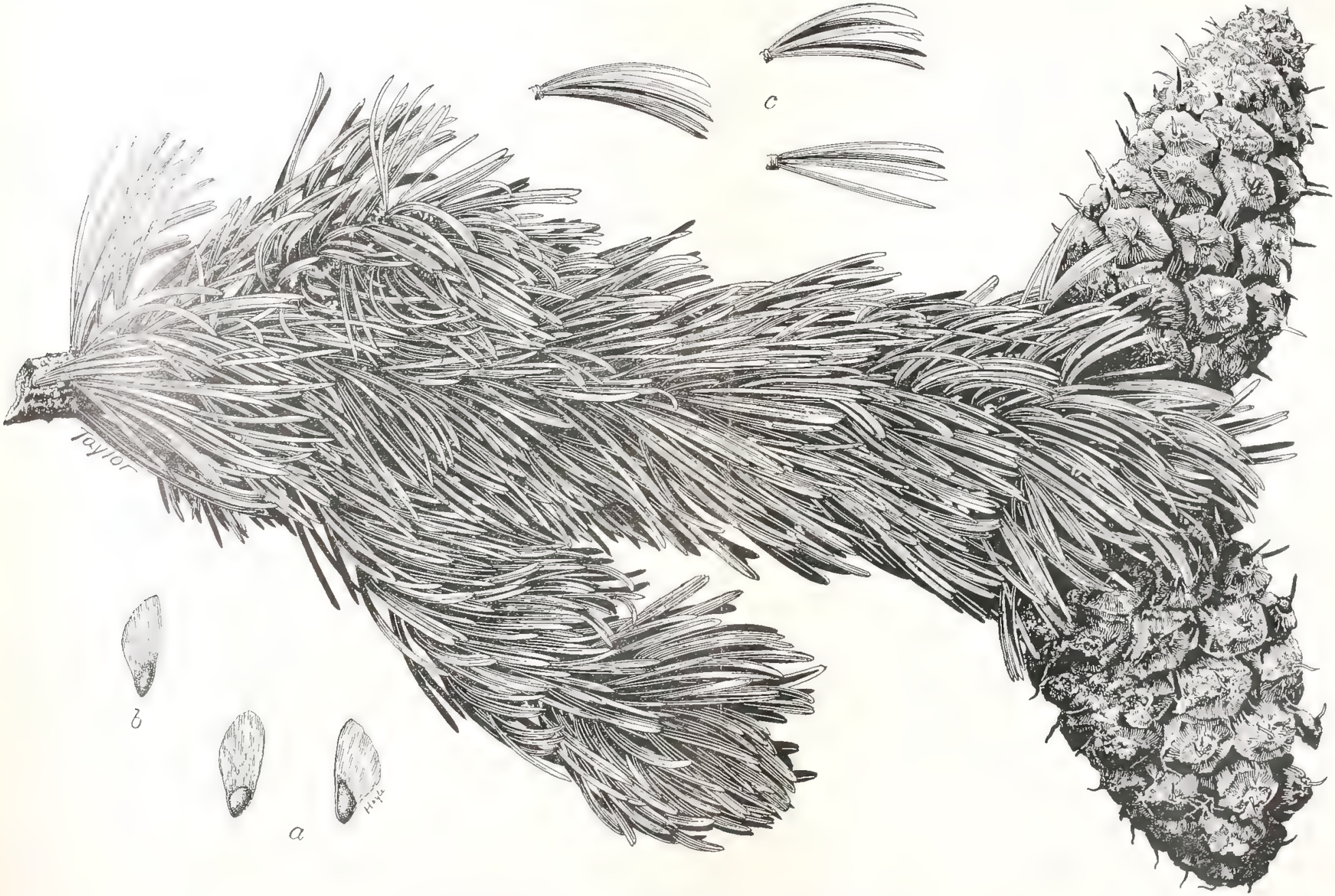
Bristle-cone pine varies in height and form from a half-prostrate twisted shrub, at very high elevations, to a bushy-crowned tree from 35 to 40 feet, in the situations more favorable for growth. Ordinarily it is from 15 to 30 feet high and from 12 to 18 inches in diameter, the tallest trees being from 20 to 30 inches or more in diameter. The trunk is clear of branches for about 6 or 8 feet. The rather wide bushy crown of long, drooping lower branches and of irregularly long upright top limbs is characteristic of single trees or those in open stands on wind-swept slopes. In denser stands, in less exposed situations, the crown form is narrower. Young trees have a distinctly pyramidal crown with short rather thick branches which stand out from the stem at right angles. The bark of old trunks is a dull reddish brown and rather shallowly furrowed, the main flat ridges being irregularly connected by narrower diagonal ones. Bark on the trunks of small trees and of the large limbs of old trees is smooth and chalky white.

The deep green foliage is densely clustered at the ends of the branches, the needles being closely pressed down (Pl. XV), in this respect closely resembling the true fox-tail pine (*Pinus balfouriana*). As a rule, the leaves are borne in clusters of 5, occasionally of 4, and are about $1\frac{1}{4}$ to $1\frac{1}{3}$ inches long (Pl. XV, *c*). The leaves of each season's growth persist for approximately 12 or 14 years.

[2] *Pinus aristata* was first introduced into cultivation at the Harvard Botanic Garden, by Dr. Asa Gray, to whom Dr. Parry sent seeds from Colorado in 1862. Dr. Gray raised a number of seedlings from this seed, and Prof. C. S. Sargent (Gard. and Forest, X, 470, 1897) states that some of these plants still growing in the vicinity of Boston had in 35 years attained heights only of from 12 to 18 inches, from which it would seem that the species is not adapted to that part of our Atlantic region, and certainly not to regions farther south. A trial of this pine near Portland, Me., shows decidedly better results. Mr. H. A. Jackson writes that trees he raised from seed planted in 1908 are now (1917) $2\frac{1}{2}$ feet high and growing thriftily. Accounts differ as to when this pine was first introduced into England, the date given in one instance (Gard. Chron. IV, 549, 1875) being 1863, and in another (Gordon, Pinetum, ed. 2, 292, 1875), 1870. It appears to be better adapted to the climate of England, where, according to Elwes and Henry (The Trees of Great Britain and Ireland, V, 1055, 1910) trees have attained heights ranging from 15 to 25 feet during a period, probably, of 35 to 40 years.

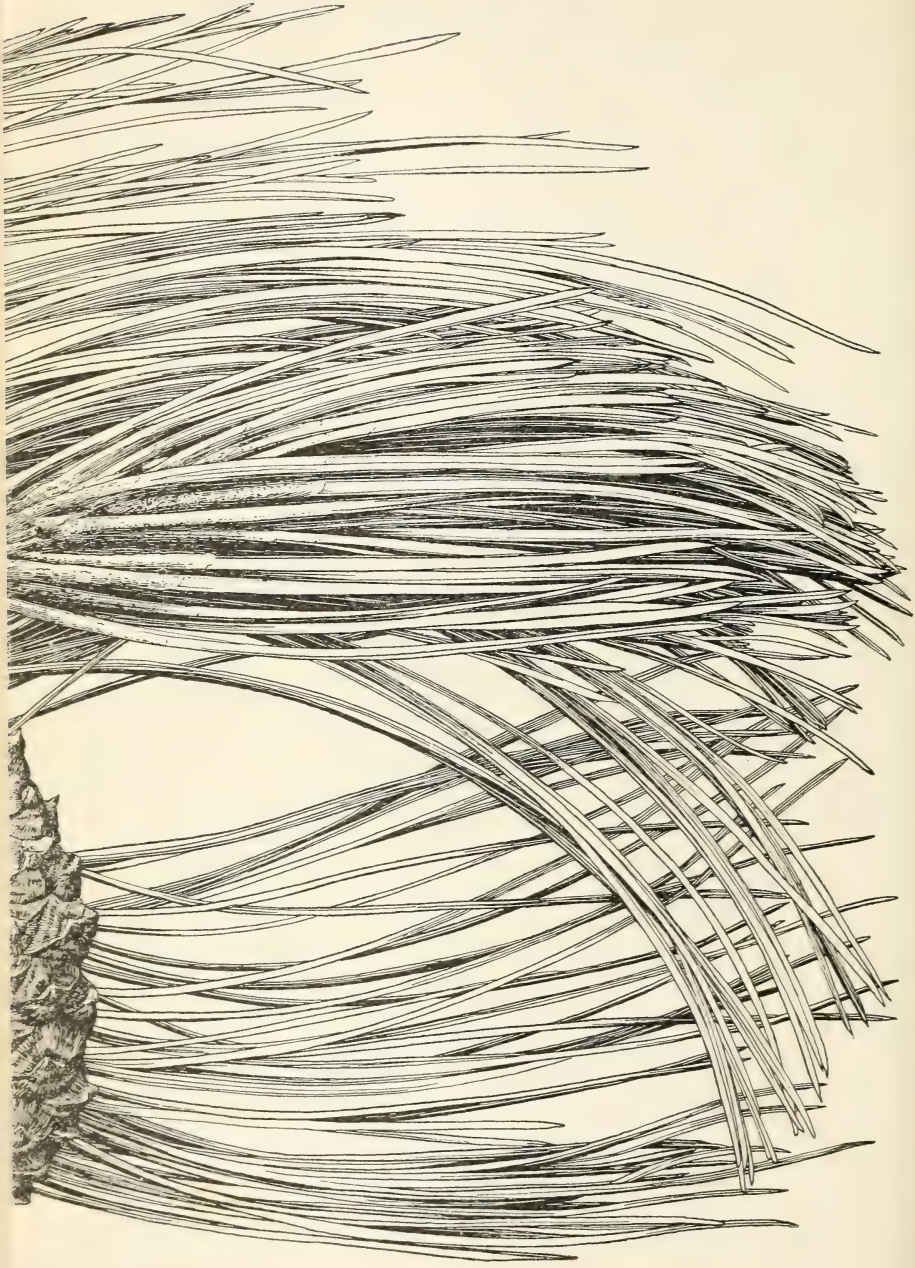


PINUS ARIZONI

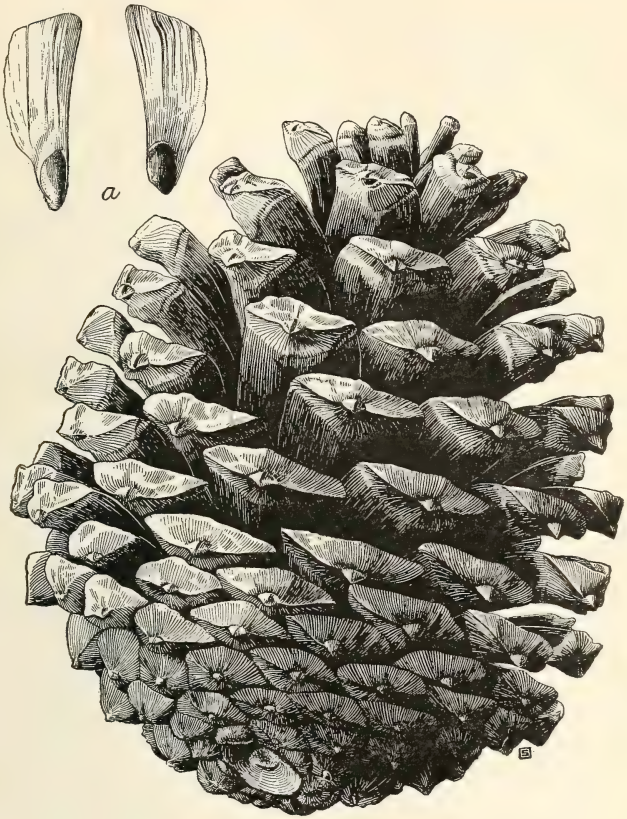


PINUS ARISTATA: FOLIAGE AND OPEN CONES; SEEDS WITH WINGS.

a, Upper side; *b*, lower side; *c*, detached leaf bundles, showing different lengths.

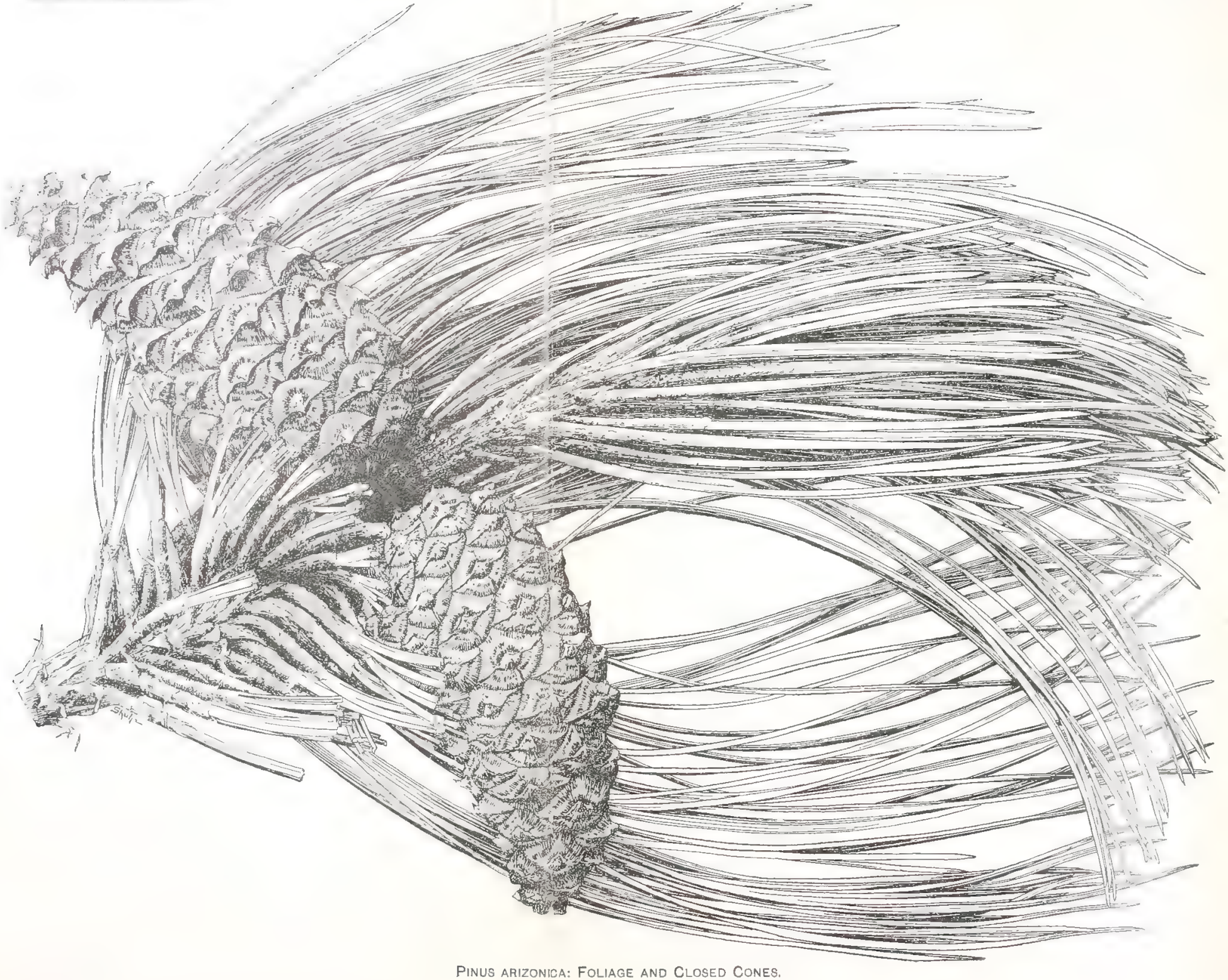


CA: FOLIAGE AND CLOSED CONES.



PINUS ARIZONICA: DETACHED OPEN CONE.

a, Upper (right) and lower sides of seeds and wings.



PINUS ARIZONICA: FOLIAGE AND CLOSED CONES.

The cones mature at the end of the second season, and are then from 2½ to about 3½ inches long and of a deep chocolate-brown color tinged with purple. Each cone scale bears a bristlelike, very fragile prickle, which easily distinguishes the cones of this pine from other species of the region. Unexposed parts of the cone scales are clear reddish brown. The seeds (Pl. XV, *a*, *b*) are pale brown with irregular black spots, and are shed from about the last of September to the middle of October. Seed-leaves of this pine vary in number from 6 to 7.

Bristle-cone pine produces rather narrow-ringed, soft, brittle wood with a thin layer of whitish sapwood and a pale brownish-red heart. It is moderately heavy for a white pine, a cubic foot of dry wood weighing about 34¾ pounds. On account of the poor timber form of the tree the wood is not used commercially. In the region of greatest abundance it is sometimes employed for fuel and mine props.

OCCURRENCE AND HABITS.

Pinus aristata is found on ridges and rocky ledges, but mainly on south slopes, here often predominating at elevations between 7,500 to 10,800 feet (Map No. 8). It grows on thin, rocky soil, and frequently on volcanic soils of cinder cones. Usually growths of this tree are in isolated situations, where snow melts early and evaporation is rapid, so that the trees are subjected to more or less prolonged dryness of soil during summer. Rarely does this species form pure stands, the trees being usually scattered over grassy ground of a gravelly or rocky nature with little or no underbrush. It is most abundant at higher levels, where limber pine is its only associate. At lower altitudes it is often associated with Engelmann spruce, limber pine, and western yellow pine, and occasionally with white fir.

Bristle-cone pine never forms dense stands, which indicates that it is intolerant of shade during the greater part of its life. Seedlings, however, endure light shade for several years without material loss of vigor.

Trees begin to bear cones when they are about 20 years old, and produce them practically every year thereafter, with specially heavy crops at intervals of several years. Reproduction is always sparse and much scattered. Seeding often takes place at a distance of at least 600 feet away from mother trees. The large number of seeds eaten by rodents and the ease with which surface fires destroy the large-winged seeds and kill the seedlings and dense-foliaged older plants doubtless account in great measure for the thin stands of this pine. Seeds germinate best in loose, exposed mineral soil, and less promptly in grass and litter. The seedlings appear to grow best on slopes with little or no underbrush.

LONGEVITY.

Little is known of the extreme age attained by this species. It is believed, however, to be moderately long-lived. Trees from 16 to 20 inches in diameter are from 200 to 250 years old.

YELLOW PINES.

Trees with rather hard, heavy wood in which the early- and late-formed portions of the annual layers are sharply defined.

ARIZONA PINE.

Pinus arizonica Engelmann.

COMMON NAME AND EARLY HISTORY.

Arizona pine is little, if at all, known to laymen, who usually mistake it for the western yellow pine (*Pinus ponderosa*). This is probably because of its close general resemblance to the latter tree, with which it is more or less associated but from which it is roughly distinguished by the greater number of leaves it bears in each cluster or fascicle.

The specific technical name of this pine, *arizonica*, suggested because the tree was discovered in Arizona, is unfortunate, for the greater part of the range lies in Mexico. Similarly, the common name "Arizona pine," derived from the technical name, is inappropriate, but it is the only distinctive one available.

Dr. John T. Rothrock, prominent in recent years in Pennsylvania forest work, discovered this tree in 1874 on the Santa Rita Mountains, southeastern Arizona. Dr. Rothrock was then serving as botanist and surgeon to an expedition under Lieut. Wheeler, who was making a geographic survey of our Southwest. The tree was technically described and given its present name, *Pinus arizonica*, in 1878. Since then no other technical names have been applied to it, and its claim as a distinct species was not questioned until 1909, when Dr. G. W. Shaw,[1] believing it to be a variety of *Pinus ponderosa*, gave it the technical name of *P. ponderosa* var. *arizonica*. The fairly constant occurrence, however, of 5 leaves in a bundle and appreciably distinct characteristics of the cones appear to be good reasons for still maintaining Arizona pine as a species.

DISTINGUISHING CHARACTERISTICS.

Arizona pine attains a height of from 75 to 90 feet, or occasionally 100 feet, with a diameter of from 30 to 50 inches. The trunks are

[1] Pines of Mexico, 24, 1909.

straight and, in mature trees, free from branches for from one-third to one-half their height. The crown form of old trees is rounded, and that of young trees broadly conical. On old trunks the bark is about 2 inches thick, very dark or blackish brown, the close, separable scales often showing light reddish brown in the deep, narrow furrows and also when freshly broken.

Each season's growth of the dark yellow-green foliage remains on the branches about two years, beginning to fall during the third season. The sharp-pointed leaves (Pl. XVI), which are borne in clusters mainly of 5 (occasionally of 2-, 3-, and 4-, with the 5-leafed clusters), are from about 4 to sometimes 9¼ inches long, but commonly from 5 to 7 inches long. The leaves produced each year vary greatly in length, even on the same tree, according to whether the season is favorable or unfavorable for growth. The leaves have close, persistent, basal sheaths from three-fourths of an inch to 1 inch long. The sheaths are a pale yellow-brown at first, later becoming grayish with exposure. The edges of the leaves have minute teeth (serratures). In cross section the leaves show three resin ducts, one in each corner of the section.

The cones (Pls. XVI, XVII), which mature at the end of the second season, are one-sided (oblique) because of the greater development of the scales on one side. They are from 2 to 3¼ inches long and externally light yellowish brown, the ends of the cone scales being more or less glossy, but becoming ash-colored with age. The upper sides of the scales are a clear cinnamon-brown, while the lower sides are a deep purplish brown. On one side of the cones the ends of the cone scales have strongly developed, sharp-edged knobs, while on the opposite side the knobs are much less prominent. All of the cone scales terminate in a delicate incurved prickle, which is usually broken off in old, weathered cones (Pl. XVII). As with the closely related western yellow pine, the cones are borne on very short stems, which remain on the branches, with a few of the basal cone scales attached, when the cones fall from the trees. Most of the cones fall during late autumn or winter following maturity and after their seeds are shed. The seeds (Pl. XVII, *a*) are provided with broad wings which are a pale cinnamon-brown. Perfect seeds are borne under all of the cone scales, except the lower 3 or 4 layers, where they are abortive. The number of seed-leaves is unknown at present.

The wood of Arizona pine is similar in general appearance to that of western yellow pine. It has a very thick layer of whitish or very light straw-colored sapwood, the heartwood being a pale reddish yellow. In old trees the wood is especially narrow-ringed and rather soft and brittle. A cubic foot of dry wood weighs nearly 31½ pounds, being slightly heavier than that of western yellow pine. The best

grades of it are suitable for many, if not all, of the commercial uses to which western yellow pine is put. Only very limited local use is made of this wood for lumber[1] in Arizona, chiefly because the tree grows in rough situations difficult of access.

OCCURRENCE AND HABITS.

Pinus arizonica occurs on dry rocky and gravelly slopes, canyon sides, and ridges at elevations between 6,000 and 8,500 feet (map No. 9). It often forms pure, quite dense stands of good saw timber at the lower elevations where the soil is less rocky, while at higher levels it grows in open scattered stands of poor form for timber. Sometimes it is associated with western yellow pine, Apache pine, and occasionally with Chihuahua pine, Arizona cypress, and white-leaf oak.

Arizona pine is intolerant of heavy shade during all periods of its growth, being similar in this respect to the western yellow pine. Seedlings, however, grow well under very light shade for 3 or 4 years. This species bears seed abundantly about every 2 years, but as a rule germination occurs only sparingly in the rougher, rockier situations, though plentifully on broken, exposed mineral soil.

LONGEVITY.

Arizona pine is probably a rather long-lived tree, attaining an age of at least 250 or 300 years. The limited number of trees studied show that those from 20 to 30 inches in diameter are from 115 to 165 years old. Further determinations are necessary, however, to establish the actual limits of age.

WESTERN YELLOW PINE.

Pinus ponderosa Lawson.

COMMON NAME AND EARLY HISTORY.

Throughout its wide distribution this tree is generally known as "yellow pine" but sometimes as "bull pine." In order to avoid confusion of *Pinus ponderosa* with other "yellow" pines it became necessary to adopt the common name western yellow pine, which is now accepted quite widely by lumbermen. The technical name *Pinus ponderosa*, which most authors apply only to the big yellow pine of the Pacific slope, is here made to include also the Rocky Mountain

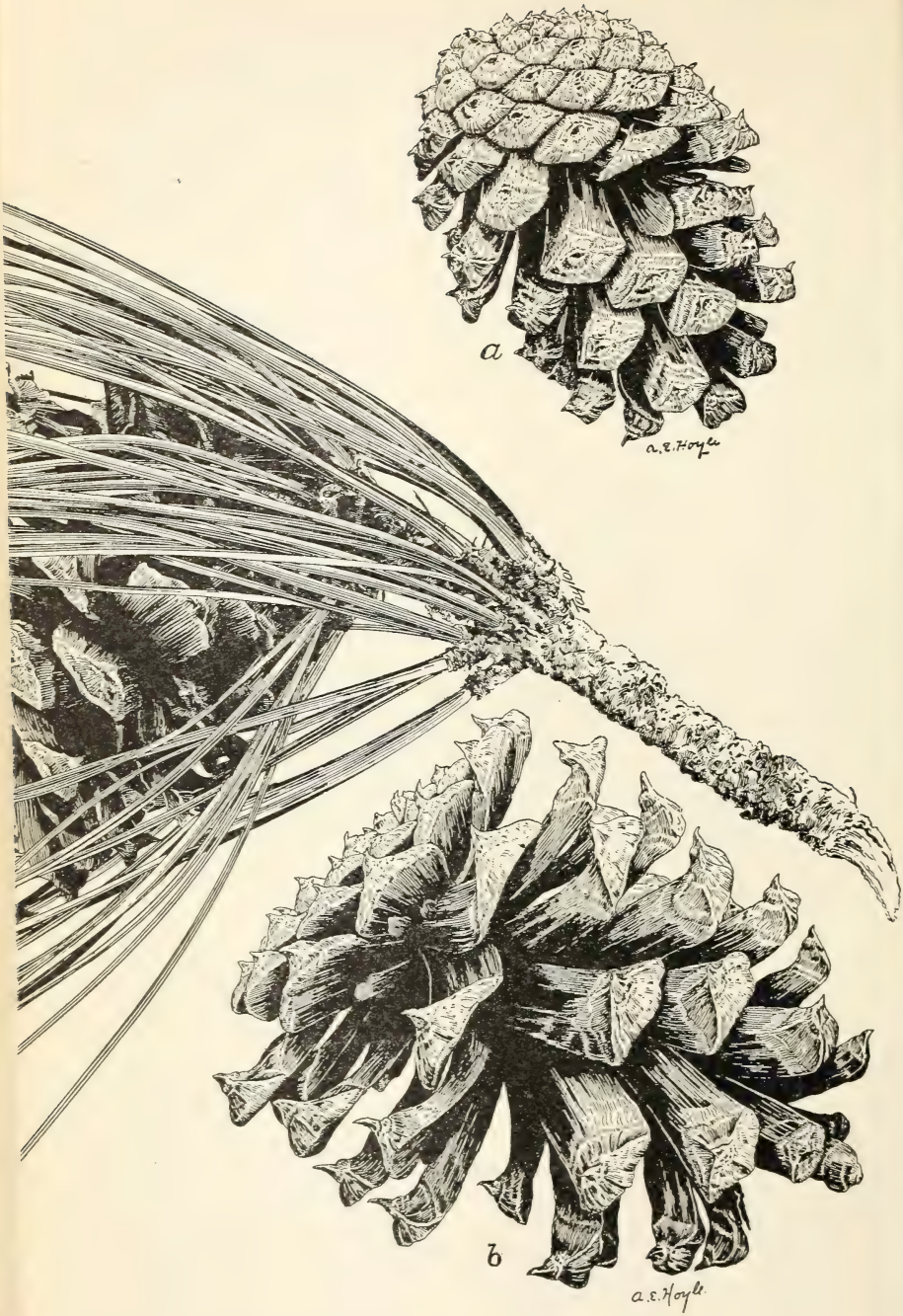
[1] It is probable that this pine is being lumbered to a considerable extent in northern Mexico, along with other hard-wooded and soft-wooded pines. Specimens collected by American prospecting timber operators usually contain Arizona pine, reported to be associated with other Mexican timber pines.

PINUS PONDEROSA: FOLI

a, Detached small form of

PINUS PONDEROSA: FOLIAGE AND CLUSTER OF OPEN CONES (ATTACHED).

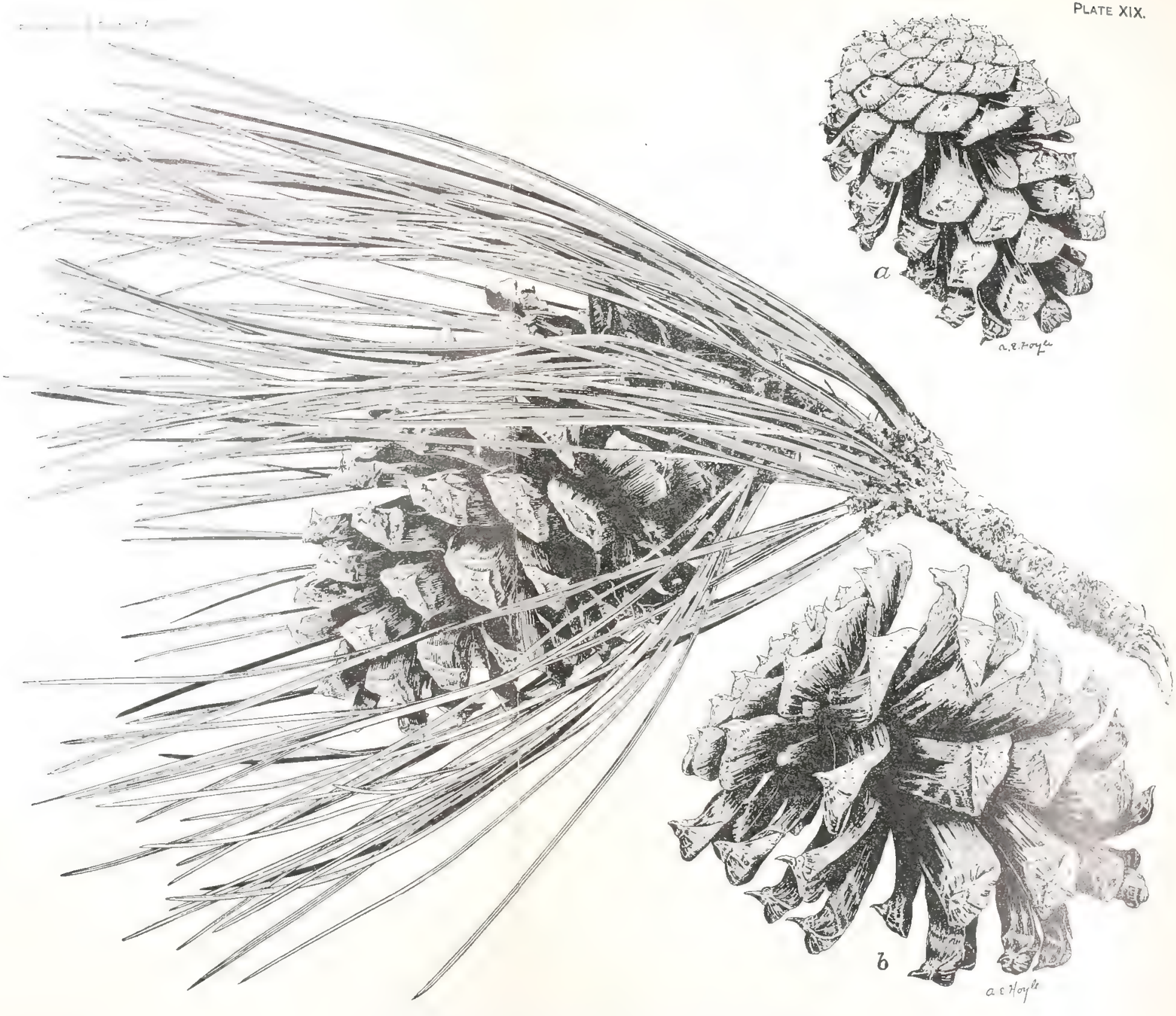
a, Upper (right) and lower sides of seeds with wings and detached seed with its wing; *b*, seedlings, one and three months old.



AGE AND SINGLE OPEN CONE (ATTACHED).

open cone; *b*, detached large form of open cone.

PINUS PONDEROSA: SHOWING TYPICAL CROWN FORM OF FULL-GROWN TREE. (ARIZONA.)



PINUS PONDEROSA: FOLIAGE AND SINGLE OPEN CONE (ATTACHED).

a, Detached small form of open cone; *b*, detached large form of open cone.

form of this pine usually designated as *Pinus ponderosa scopulorum.*[1]

The earliest published notice of western yellow pine is in the journal of the Lewis and Clark expedition, which records that in 1804 cones of a pine (now believed to be western yellow pine) were found floating in the White River and doubtless came from a growth of this species in northwestern Nebraska. To David Douglas, however, belongs the credit of having first brought this tree to the notice of dendrologists by his discovery of it in 1826 on the Spokane River, Wash. The following year (1827) he sent seeds to the London Horticultural Society, from which a tree was raised in the Caledonian Horticultural Society's garden.[2] The first technical description was taken from this tree; and its present name, *Pinus ponderosa*, was established for the first time by Lawson[3] in 1836, although David Douglas had previously proposed this name (but without a definite

[1] A long field study of the Rocky Mountain form of the western yellow pine and of the generally longer-leafed yellow pine of the Pacific region has convinced the writer that the two are geographic forms only of one widely distributed species, which was technically described first in 1836 as *Pinus ponderosa*. The Rocky Mountain yellow pine is, therefore, here united as a silvical form with the Pacific slope yellow pine, under the name *P. ponderosa*. The writer can find no constant characteristics to separate satisfactorily the Pacific slope tree from its so-called variety "*Pinus ponderosa scopulorum*" of the central and southern Rocky Mountain region. The most distinctive types of "*P. ponderosa scopulorum*" occur in the Dakotas, Nebraska, eastern Wyoming, adjacent sections of Colorado and in Texas, where the leaves are shorter and the cones smaller than are generally found on trees occurring west of these outlying sections. Short-leafed and small-coned trees are, however, not infrequent in the central and southern Rockies, along with leaf and cone forms that are clearly intermediate between the most eastern and the interior mountain trees. Marked differences in the soil and climatic conditions under which the short-leafed and the longer-leafed trees grow can easily account for the supposed specific and varietal distinctions relied upon to separate the Rocky Mountain yellow pine from the Pacific tree. It seems much wiser to consider the trees of these two regions silvical forms of one variable species than to try longer to maintain them as distinct by characteristics which are clearly only individual variations. Exactly parallel cases are the attempted separations of the Rocky Mountain form of lodgepole pine from the Pacific coast form and of the Rocky Mountain form of Douglas fir from the Pacific slope form, both of which grow under totally different soil and climatic conditions.

[2] Elwes and Henry (The Trees of Great Britain and Ireland, V, 1074, 1910).

[3] Agric. Manual, 354, 1836. The Pacific slope form of *Pinus ponderosa* appears to be well adapted to the climate of England, where, according to Elwes and Henry (opus cit., 1076), several trees raised from Douglas's seed, sent in 1827, and planted in 1829, were living in 1909 and had attained heights of from 96 to 104 feet, with diameters of from about 26 to 35 inches. Many other trees planted since then are said to be in thriving condition. As might well be expected, it is successfully grown there only in well-drained soils. The German Government in the early nineties imported considerable quantities of seed of the Pacific slope form of this tree for experiments in forest planting. The stock raised grew well for several years and then died from some unknown cause (Schwappach, Anbau. Fremdl. Holzart., 57, 1901). Presumably, however, the Rocky Mountain form would have proved to be adapted to German conditions. Trials of both the Pacific slope and the Rocky Mountain form of *Pinus ponderosa* in the region of New England have not been successful (fide, Sargent, Gard. and For., 470, 1897). It is too early yet to predict the success of this tree set in forest experimental plantations in the Letchworth Park Forest and Arboretum at Portage, Wyoming County, N. Y., where so far, however, 3 to 5 year old stock raised from Rocky Mountain seed is in thrifty condition and promises to grow well. A single tree now standing in the grounds of the U. S. Department of Agriculture, Washington, D. C., raised from seed collected in the Pacific slope region, was planted here about 30 years ago by William Saunders. Its growth has, however, been exceedingly slow, the height being about 15 feet.

description of the tree's characteristics) in his account of the discovery of the species published in 1836.[1]

The botanical history of western yellow pine is full of perplexities. During the three-quarters of a century the tree has been known, no less than 15 different technical names have been applied to different or the same forms of the tree, some of which were described as distinct species and others as varieties. Much, if not all, of this confusion is probably the result of a study of herbarium specimens only, rather than of the tree as it grows under the different soil and climatic conditions within its extensive range (Map No. 10).

DISTINGUISHING CHARACTERISTICS.

Pinus ponderosa is a massive, straight-trunked tree with a long, narrow, open crown of hugely developed, bent branches. The narrow columnar form of the crown, with its scattered branches, upturned at their ends, is very characteristic. Often one or two large lower branches are separated from the crown by 20 or more feet of clear trunk. Trees grown from the first in an open stand usually bear branches close to the ground, retaining this long, low crown throughout life (Pl. XX). The trunk is cylindrical, with little taper until the large crown branches are reached. Its majestic size is surpassed by no other native pine except the sugar pine of California. In general the height is from 125 to 140 feet, with a practically clear trunk of from 40 to 60 feet, and a diameter of from 3 to 5 feet. Unusually large trees are from 150 to 180 feet high, while trees are said to have been found over 200 feet high. The largest diameter recorded is about 8 feet. The form of western yellow pine found in the central and southern Rockies ranges from 60 to 125 feet in height and from 20 to 30 inches in diameter, or occasionally somewhat larger. The bark of old trunks is marked by very broad, shield-like, russet-red plates, which may be from 3 to 4 inches thick, especially near the base of the tree. The bark is peculiarly made up of small, concave scales. Younger trees, up to 2 feet in diameter, are quite unlike older ones in having dark red-brown or blackish, narrowly furrowed bark.[2] Young shoots, which have a strong odor of orange when broken, are yellowish green and later brownish.

[1] Companion to the Botanical Magazine, ii, 111. 1836.

[2] Lumbermen in the range of western yellow pine distinguish two forms of the species, one of which they call "black jack" and the other "yellow pine." The two forms are botanically alike, but distinguished by striking differences in the color and markings of the bark, which appear to be due entirely to age. Trees up to about 150 years of age commonly have blackish, narrowly ridged bark and are, therefore, known as "black jack," while trees older than these usually have light reddish-brown bark broken into broad, flat ridges, such trees being called "yellow pine." The young growths of several eastern pines are also distinguished as "black jack," most lumbermen who apply the name knowing, however, that it is an age designation rather than one of species.

The foliage, borne in heavy brush-like clusters at the ends of bare branches, is a deep yellow-green. The leaves (Pls. XVIII, XIX) occur in bundles of 3 (sometimes of 2 and rarely of 4 and 5, and then chiefly on saplings). They vary in length from about $4\frac{3}{4}$ to $11\frac{1}{4}$ inches. Each season's growth of leaves remains on the tree about three years. The edges of the leaves have minute teeth (serratures). A cross section of the leaves shows from 2 to 5 resin ducts, the usual number being 2.

The cones (Pls. XVIII, XIX) mature early in August of the second season and shed their seeds mainly during September. The cones of some trees are a bright grass green when mature, while those of other trees are a dark purple, there being no other essential difference between trees bearing cones so dissimilar in color. Cones vary in length from $2\frac{3}{4}$ to about $5\frac{3}{4}$ inches and in width from $1\frac{1}{2}$ to about 2 inches. The ends of the cone scales are russet-brown and shiny. After the seeds are shed, the cones begin to fall, and by early winter they are all down. A notable characteristic of the cones of this pine is that when they break away from the branch some of the basal scales are left on the tree. The seeds (Pl. XVIII, *a*), which vary greatly in size, are marked with purple spots and blotches on a dull yellowish ground, while the wings are a light purple-brown. The number of seed-leaves varies from 5 to 9 (Pl. XVIII, *b*).

Western yellow pine wood is narrow-ringed, the rather thick layer of sapwood being nearly white and the heartwood ranging from a pale lemon-yellow to an orange-brown or a reddish yellow. It varies greatly in texture according to the age of the tree. Young trees have moderately hard, resinous, strong wood; the wood of old trees is brittle, only slightly resinous, and very soft—so much so that lumber cut from such trees is sold as "white pine." In general a cubic foot of dry wood weighs from about $28\frac{3}{4}$ to $29\frac{3}{4}$ pounds. The weight of wood from very old, slowly grown trees would probably not exceed about 25 pounds per cubic foot. It is one of the most valuable commercial woods produced in the Rocky Mountain region, being used for all sorts of dimension timber under cover, for interior and exterior work, railroad ties, mining timber, fuel, etc. It is, however, only moderately durable in contact with earth or when exposed to the weather in an unprotected state.

OCCURRENCE AND HABITS.

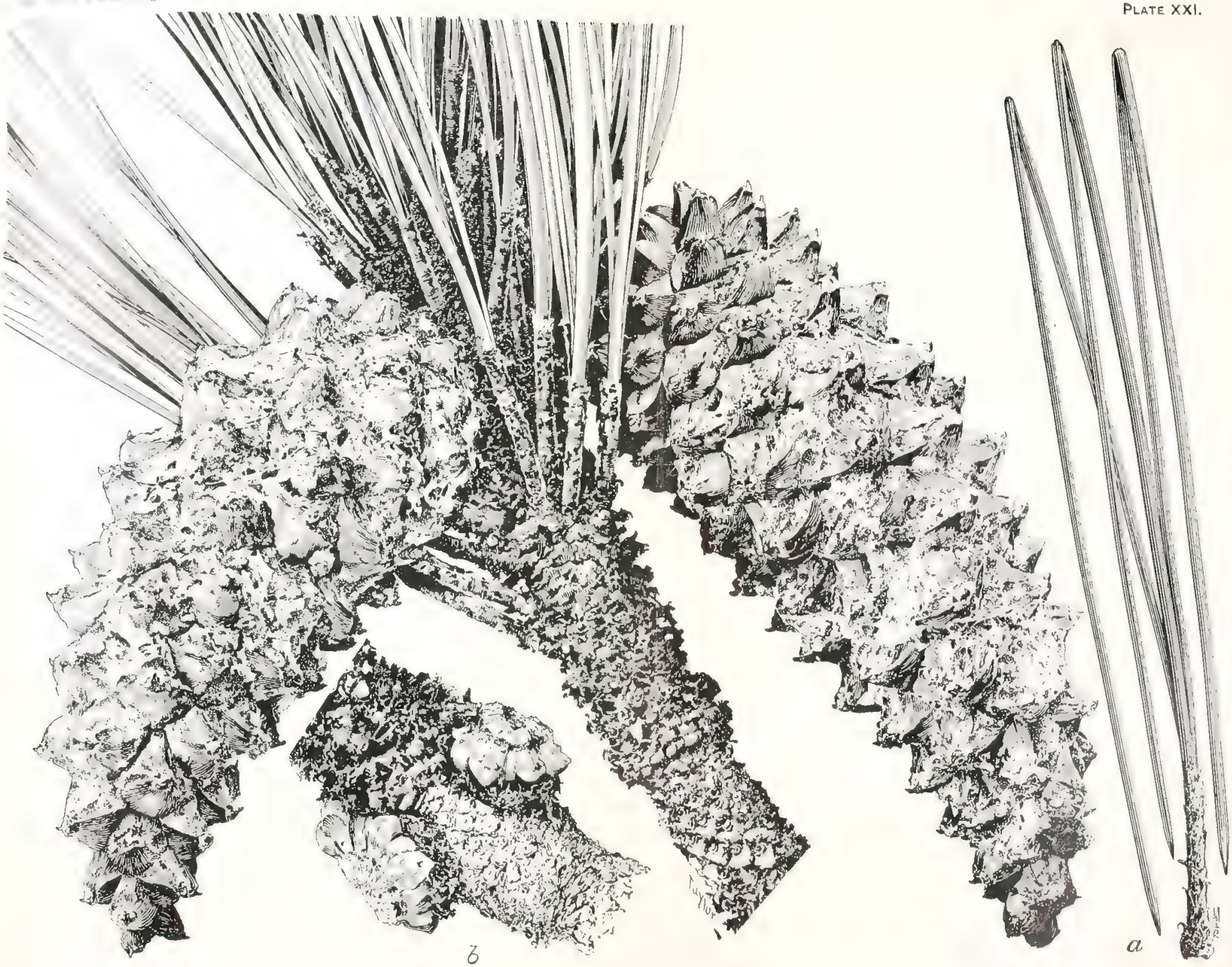
Western yellow pine occurs on dry and moist slopes, on the tops of ridges and in canyon bottoms, in general at elevations between 1,800 feet (Pacific region) and 10,300 feet (southern Rockies), the main forest growth in the Rocky Mountain region being found be-

tween 5,000 and 8,500 feet (Map No. 10). It is very moderate in soil requirements, growing on all soils from glacial drift and volcanic ash to deep, loose sands and stiff clays. Dry, well-drained sandy or gravelly soils are, however, most characteristic. Once established, it requires very little moisture in the upper layers of earth; for the enormously deep roots enable it to thrive in soils apparently as dry as those in which piñon pines and junipers grow.

Pure extensive stands are formed; and it occurs also in mixture occasionally with broad-leafed trees, but more commonly with western larch, Douglas fir, and white fir, and sometimes with Arizona pine and Mexican white pine. Open grassy park lands are often interspersed, and, as a rule, little or no underbrush, or even grass, occurs in these forests because of frequent fires.

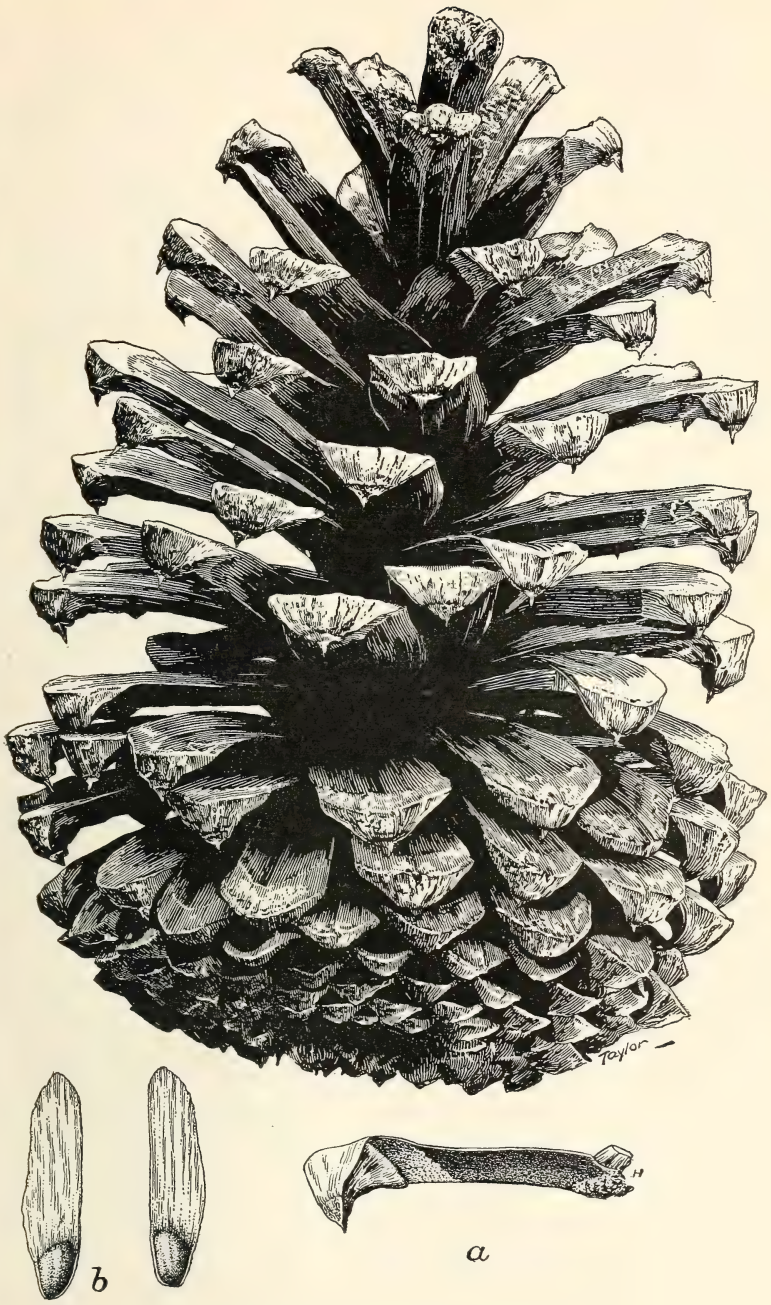
Pinus ponderosa demands an abundance of light throughout its life, particularly after the pole stages. Young stands may remain dense for from 10 to 15 years, but subsequently they thin out rapidly. Trees above 20 feet in height require almost unbroken light. Those in mature stands are rarely closer than 30 feet, and the crowns seldom touch. In the South, however, seedlings do not endure intense light and heat, usually coming up in the shade of old trees, or in openings near logs, bowlders, and brush which afford slight protection. In the North, where the light is less intense, they grow commonly in unprotected openings.

Pinus ponderosa is a frequent and abundant seeder. Cones are locally produced about every year, so that there is always some seed in a forest; but specially good seed years occur only at intervals of from 3 to 5 years. Germination from natural dissemination, in which much of the seed fails to come in contact with mineral soil, is usually about 50 per cent; while germination from artificial sowing, in which the seed is in close contact with the soil, is from 60 to 80 per cent. Well-drained, fresh soils, and a moderate daily range of temperature are necessary for germination. Trees from 20 to 25 years old produce seed; but generally the quantity is limited and the quality poor until the trees are about 50 years old. Large, thrifty trees produce over 1,000 cones, the average amount of seed per tree amounting to from 1 to 6 pounds. The seed is not wafted far from the mother trees in the closer stands, but in open ones it may be carried by the wind for from 500 to 700 feet. A mature tree can seed about one-fourth of an acre in a good seed year. Squirrels and birds eat considerable quantities of seed. The rodents, however, disseminate some seed as a result of their habit of storing it for food; but reproduction from this source is accidental. Much seed is washed down steep slopes to stream beds and depressions, where good reproduction often occurs.



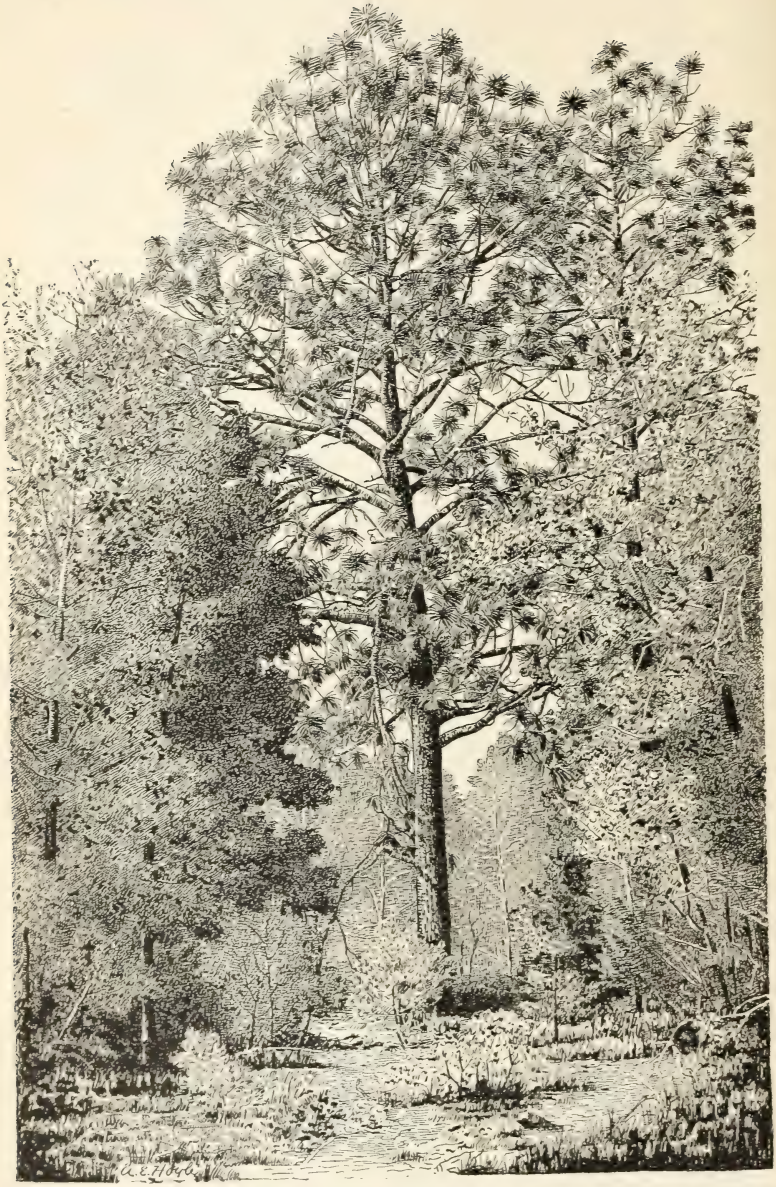
PINUS APACHECA: FOLIAGE AND RIPE CLOSED CONES.

a, Detached leaf bundle; *b*, part of branch showing basal scales of mature cone that has fallen away.

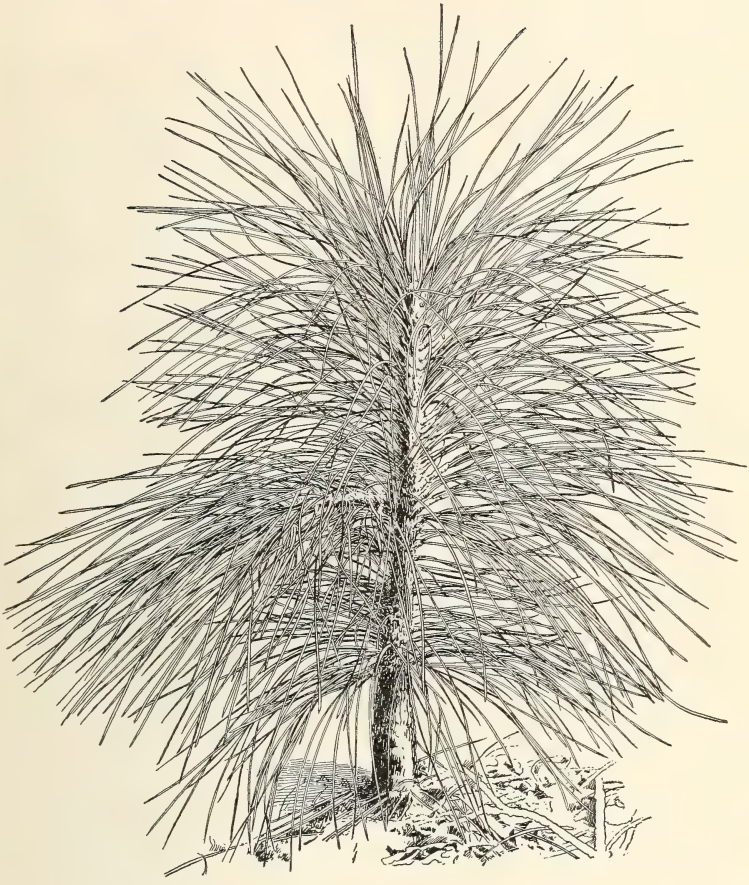


PINUS APACHECA: DETACHED OPEN CONE.

a, Detached cone scale (side view); *b*, upper side of seeds with wings.



PINUS APACHECA: SHOWING CROWN FORM IN OPEN STAND; 40 FEET HIGH AND 20 INCHES IN DIAMETER.



PINUS APACHECA: YOUNG TREE (SIX YEARS OLD) 30 INCHES HIGH.

LONGEVITY.

Western yellow pine is in general a long-lived tree, attaining an age of from 350 to 500 years. In the central and southern Rocky Mountain region, it appears to be shorter-lived than in the northern part of this region and on the Pacific slope, trees in the central and southern regions probably not attaining an age of over 250 or 300 years.

APACHE PINE; "ARIZONA LONGLEAF PINE."

Pinus apacheca Lemmon.

COMMON NAME AND EARLY HISTORY.

This comparatively rare species is practically unknown to settlers and other laymen, with whom, for the most part, it passes as "yellow pine." The name "Apache pine," derived from the technical specific name, is a book name probably not yet used in the field, but one which may be appropriately adopted. "Arizona longleaf pine" has been applied by United States forest officers in the Arizona range of the tree, but as the species occurs elsewhere in our Southwest this name would seem to be inappropriate.

Until recently Apache pine (*Pinus apacheca*[1]) and the Mayr pine (*P. mayriana*) were believed to be distinct species. The writer is now convinced, however, that they are one species, which is distinct from other southwestern pines.[2] Dr. J. G. Lemmon discovered *Pinus apacheca* in 1881 in the Chiricahua Mountains, Arizona, and under this name he published a figure and description of it in 1894. Dr. Mayr next found it in 1887 in the Santa Rita Mountains, Arizona; and in 1889 it was described and named "*Pinus latifolia* Sargent," which, being found to be a synonym, was replaced in 1897 by "*Pinus mayriana*."[3] As Dr. Lemmon's name, *Pinus apacheca*, was published

[1] Erithea, II, 103, Pl. III. 1894. (See also footnote 1 in the present work, on p. 34.

[2] *Pinus apacheca* appears to be closely related to *Pinus engelmanni* Carrière, which is a Mexican species not known to occur in the United States. Dr. George Russell Shaw relates the Apache pine to our western yellow pine under the varietal name "*P. ponderosa* var. *macrophylla*," a name which appears to be preoccupied by Lindley's *Pinus macrophylla* published in 1839, the latter now being considered a synonym of *P. montezumae* Lambert (1803). Later comparative study may possibly show that *P. apacheca* is a northern form of *P. engelmanni* Carr. In describing the latter tree Dr. Engelmann, who first characterized it as a new species, unfortunately under the preoccupied name *P. macrophylla*, mentions the close resemblance it bears to *P. australis* (=*P. palustris*). In the opinion of the present writer the general appearance of the two trees is strikingly similar; and, as is shown further on, the seedling growth (Pl. XXIV) of *Pinus apacheca* and *P. palustris* is very much alike and equally unlike the early growth of any other southwestern pine.

[3] Nomenclature of the Arborescent Flora of the United States (Bull. 14, Division of Forestry), 21. 1897.

3 years before *P. mayriana* Sudw.[1] appeared in print, it would seem that the tree must now be known by the earlier established name, *P. apacheca.*

DISTINGUISHING CHARACTERISTICS.

The general appearance of the large, long, deep-green leaves of Apache pine distinguish it from all associated species, and remind one of the southeastern longleaf pine (*P. palustris*). Young trees (from 5 to 6 years old and from 2 to 3 feet high) are also strikingly similar in appearance and habit to the early growth of young longleaf pines (Pl. XXIV).[2] The crown and trunk form of large trees is, however, similar to western yellow pine. Such trees have rather open, elongated, or round-topped crowns, and straight trunks clear of limbs for from one-third to one-half their height (Pl. XXIII). Young trees (Pl. XXIV) have broadly conical, rather compact crowns and trunks clear of branches for about one-fourth their height. Mature trees are from 50 to 75 feet high and from 14 to 30 inches in diameter. Doubtless larger trees occur. The bark of both old and young trunks is rather narrowly and deeply furrowed, the main ridges being connected by smaller side ridges. It varies in thickness from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches. Externally the bark is dark brown, newly opened rifts showing dull red-brown.

The stout dark-green leaves (Pl. XXI, *a*), which bear minute teeth (serratures) on their margins, occur mainly in bundles of 3 (exceptionally of 2, 4, and 5) and are commonly from 8 to 15 inches long, some trees bearing leaves 6 to 7 inches long. A cross section of the leaves shows from 11 to 14 resin ducts. Each season's growth of leaves remains on the tree about 2 years. The basal sheaths of the leaf-bundles, at first light brown and later dark brown, are from three-fourths of an inch to $1\frac{1}{2}$ inches long and have conspicuously fringed margins.

The cones (Pls. XXI, XXII), matured at the close of the second season, are commonly from 4 to $5\frac{1}{2}$, or sometimes nearly 6, inches long and externally a light yellowish or clay-brown, unexposed parts of the cone scales being a dark chocolate-brown. They are more

[1] The history of this species is as follows: Dr. C. S. Sargent first described it as *Pinus latifolia* (Gard. and For. II, 496, fig. 135, 1889) from specimens collected by Dr. Mayr while exploring our Southwest. Later, the present writer found the specific name "*latifolia*" to be preoccupied in previously published trinominals applied to two different pines, thus making it impossible to retain longer *P. latifolia* for the Arizona pine. The latter was, therefore, renamed *P. mayriana* in 1897, in honor, as was then supposed, of its first discoverer, Dr. Heinrich Mayr. This name must, however, now become a synonym of *Pinus apacheca* Lemmon, which appears to be the first name applied to the tree. Dr. Sargent's present judgment is that the "Mayr pine" is a variety only of the western yellow pine and he has accordingly designated it as *P. ponderosa mayriana* (Silva, XI, 81. 1897).

[2] The tap-root of seedlings descends to great depth during the first 5 or 6 years; while the stem above ground grows very slowly in height, and rarely branches. In this habit of growth, young plants differ greatly from the western yellow pine and Arizona pine, and strongly resemble the longleaf pine (*Pinus palustris*) in its first few years' growth.

or less one-sided (oblique), which is due to the greater development of scales on one side (Pl. XXI). In falling from the branches the cones leave a few basal scales attached to the limbs (Pl. XXI, *b*), as in the case of *Pinus ponderosa* and other yellow pines of this group. The ends (umbos) of the cone scales are recurved, elongated (especially on the fuller side of the cone), sharply two-sided, the extreme ends being contracted abruptly to a short delicate prickle (Pl. XXII, *a*). The seeds (Pl. XXII, *b*), are a dark chocolate-brown (deeper on the lower side) and from about five-sixteenths to three-eighths of an inch long. Perfect seeds are produced chiefly in the middle third of the cone, many scales bearing only one seed. The seed-leaves vary from 8 to 10, averaging about 9.

The wood of Apache pine is rather heavy (actual weight undetermined), hard, somewhat "cross-grained," and uniformly wide-ringed, the darker bands of late wood forming from one-third to about one-half the annual layers of growth. The wide-ringed character of this wood is due probably to the fact that the trees usually grow in scattered open stands where an abundance of light stimulates diameter growth.

OCCURRENCE AND HABITS.

Pinus apacheca grows in the rocky gravelly soils of benches, gulches, and gentle slopes, at elevations of from about 5,700 to 8,200 feet, and usually in moderately moist situations (map No. 11). It forms a very open stand or is widely scattered, and is associated more or less with Arizona pine, Chihuahua pine, western yellow pine, Arizona oak, whiteleaf oak, and huckleberry oak.

It is intolerant of shade except during the first five or six years of its life.

Apache pine bears abundant crops of seed; good seed years occur only at intervals of about two or three years, but some seed is produced practically every year in parts of the tree's range. Wind carries the large-winged seeds (Pl. XXII, *b*) several hundred feet from the parent trees, but as many of them fall where germination can not occur for lack of soil cover, reproduction is not abundant and is always scattered. Reproduction occurs most readily on broken and washed mineral soil. The seeds of this pine are favorite food of birds and rodents, which consume large numbers of them.

LONGEVITY.

The age limit of Apache pine is imperfectly known at present, but the tree probably attains an age of from 175 to 200 years. Trees from 15 to 18 inches in diameter are from 65 to 90 years old, and trees 20 to 28 inches are from 100 to 140 years old. Between the ages of about 8 and 75 years this pine appears to grow rapidly in height and diameter.

CHIHUAHUA PINE.

Pinus chihuahuana Engelmann.

COMMON NAME AND EARLY HISTORY.

Chihuahua pine is a little-known species which has no distinctive common name in the United States, probably because it is not often distinguished by laymen from the other yellow pines with which it is more or less associated in our Southwest (map No. 12). It is known to a few lumbermen in Mexico as "black shortleaf pine." The name "Chihuahua pine," derived from the specific technical name, is suggested here as appropriate, because the tree occurs extensively in Chihuahua, Mexico.

Pinus chihuahuana was discovered in the western part of Chihuahua by Dr. A. Wislizenus in 1846, and in 1851[1] Dr. J. M. Bigelow, a botanist of the Mexican Boundary Survey Expedition, was the first to find it in our Southwest (vicinity of Copper Mines, southern New Mexico).[2] Chihuahua pine was technically named and described as a species for the first time in 1848; from then until 1909 there has been a general agreement among botanists regarding its claim to specific rank. In 1909 Dr. G. R. Shaw,[3] believing it to be a variety of the Mexican *Pinus leiophylla* Schl. and Cham., designated it as *P. leiophylla* var. *chihuahuana.* He based the relationship upon the triennial fructification[4] of these two pines, and also upon the habit both have of sprouting from the stump.[5] Chihuahua pine is here maintained as a distinct species because of the commonly constant occurrence of its leaves in clusters of 3, the leaves of *P. leiophylla* occurring almost invariably in clusters of 5.

DISTINGUISHING CHARACTERISTICS.

Chihuahua pine is a small or medium-sized tree as it occurs in our Southwest, varying from 35 to 60 feet in height and from 1 to 2 feet in diameter. The fairly straight trunks are clear for one-half or two-thirds of their length, and the usually large branches have an upward trend, forming a narrow pyramid-shaped crown. Compared with other associated yellow pines the foliage appears thin and pale. The trunk bark, composed of thin, closely adhering scales, varies from a blackish brown to a very dark brown and is commonly bright red-brown in the deep rifts. It is from about seven-eighths

[1] Fide Sargent, Silva, XI, 86, 1897.

[2] Fide Torrey, Botany of U. S. and Mexican Boundary Survey, 209, 1858.

[3] The Pines of Mexico, 14, 1909.

[4] Dr. George Engelmann and Prof. C. S. Sargent discovered in 1880 that *Pinus chihuahuana* requires 3 years in which to mature its cones (Botanical Gaz., VII, 4, 1882).

[5] Chihuahua pine sprouts freely from stumps in its range within the United States; but the writer hesitates to rely upon this as a dependable indication of relationship to the Mexican *Pinus leiophylla*, for the reason that the sprouting propensities of *Pinus echinata*, *P. rigida*, and *P. pungens*, at some ages and under some conditions, could hardly be relied upon to show varietal relationship of these pines.

PINUS CHIHUAHUANA.

a. Foliage and close cones; *b*, detached 3-leafed and 5-leafed bundles; *c*, open cones; *d*, upper (right and left) and lower (center) sides of seeds with wings

of an inch to 1½ inches thick, deeply and narrowly furrowed, and with long, wide, interrupted ridges.

The slender, bluish-green or grayish-green leaves (Pl. XXV, *b*) occur in bundles of 3 (occasionally of 4, and exceptionally of 5), and when full grown are without basal sheaths (common to other associated yellow pines). The short, papery, scaly sheaths of immature leaves remain attached only until the end of the first summer or autumn. Mature leaves are from 2 to 4¼ inches long, but usually about 3 inches. The edges of the leaves have minute, distinct, sharp teeth (serratures). A cross section of the leaves shows two resin ducts. Each season's growth of leaves persists for about 3 years, being shed during the fourth season.

The cones (Pl. XXV, *a*, *c*), matured in September of the third season,[1] are from about 1½ to 2⅝ inches long, and are borne on a short, rather slender, curved stem from three-eighths to five-eighths of an inch long (Pl. XXV, *c*). Mature cones are at first a light, yellowish brown, later becoming dull gray by exposure to the weather. Unexposed parts of the cone scales vary from a light to a deep purple brown. The slightly thickened ends of the cone scales have a low, sharply defined ridge and bear delicate prickles, which gradually disappear as the cones become older. Mature cones adhere to the trees 5 or more years, and when they fall they usually retain their stems. The chocolate-brown seeds (Pl. XXV, *d*) have pale yellowish-brown wings delicately splashed with darker brown. The number of seed-leaves is unknown at present.

In general the wood of Chihuahua pine is moderately narrow-ringed and straight-grained and rather hard. The light straw-colored, thick layer of sapwood, containing from 50 to 60 annual layers of growth, contrasts strongly with the reddish-yellow heartwood. A cubic foot of dry wood weighs about 34 pounds, being considerably lighter than that of western yellow pine but having its good working qualities. The best grades are equal to western yellow pine for commercial purposes. The comparatively small size and limited supply of this tree available in our Southwest, however, prevent it from being used for lumber.[2]

OCCURRENCE AND HABITS.

This species occurs on dry, rocky, gravelly mountain slopes and benches at elevations between 5,500 and 8,200 feet (map No. 12). The thrifty growth of this tree in moist and rich soils shows that it can profit by such favorable conditions, the growth in drier situa-

[1] *Pinus chihuahuana* is exceptional among western pines in that its male and female flowers do not appear until July, which is much later than in the case of other pines of its range.

[2] The Chihuahua pine attains large dimensions in Mexico, where it is probably being lumbered along with such associated timber pines as *Pinus arizonica*, *P. ponderosa*, and *P. strobiformis*.

tions being much less vigorous. It forms pure open stands of limited extent (in the United States) and is also scattered among open forests of Arizona pine, western yellow pine, and occurs occasionally with Apache pine. Its requirement of light is very similar to that of the western yellow pine.

Chihuahua pine bears good crops of seed about every other year, but some cones are ripened practically every year. Reproduction is, however, generally sparse, which is due in part probably to the fact that mature cones often remain closed for several years, thus failing to liberate their seeds regularly.

LONGEVITY.

Chihuahua pine is moderately long-lived, probably attaining an age of from 250 to possibly 300 or more years. Further determinations are required to establish its extreme age. Trees from 14 to 20 inches in diameter are from 125 to 185 years old.

LODGEPOLE PINE.

Pinus contorta Loudon.

COMMON NAME AND EARLY HISTORY.

Lodgepole pine is one of the most interesting of our native species on account of its variable characteristics and its enormously wide range (map No. 13), which extends from sea level to 11,500 feet elevation. For many years authors have endeavored to maintain that the form of lodgepole pine which inhabits the region from our northern Pacific coast to the western Cascades is distinct from the lodgepole pine that grows on the high Sierras and Rocky Mountain plateaus. The first is known to botanists as *Pinus contorta* and the last, as *Pinus murrayana* and *Pinus contorta murrayana.* The distinctions assembled to separate these trees are, however, one after another broken down when living trees are carefully studied throughout this great region. In the opinion of the writer such distinctions as differences in thickness of bark, size of cones and leaves, or size and form of the tree, may, in the case of these two forms, be consistently within the variations of one polymorphous species. Moreover, the reproductive organs of these supposedly distinct trees being essentially the same, they offer no characteristics on which to base varietal or specific distinction. Perhaps no other North American trees have given so much trouble, or left so much uncertainty in the minds of those who have attempted to hold them separate, as the coastal and high-mountain forms of this pine. Recent students of trees certainly have appreciated the lack of distinction between these two regional forms, but have been slow to depart from the time-honored judgment of earlier writers. It is confidently believed, however, that the latter would have taken the broader view had they been able to study the trees as they grow in all their retreats.

The Pacific coast form of this species is commonly called "scrub pine," because it is stunted, and sometimes "sand pine" and "shore pine," owing to the fact that the tree grows on the sandy seashore. The high-mountain form, however, particularly of the Rocky Mountain region, is most widely known as lodgepole pine, a name which is descriptive of the trunk form over most of the tree's great range and therefore appropriate. "Tamarack," "spruce pine," and "Murray pine" are local names also applied to the mountain form of this species.

The high-mountain form of this tree is believed to have been discovered by Lewis and Clark[1] in 1805 on mountains above the headwaters of Jefferson River (in the present Absaroka National Forest), western Montana, while the Pacific coast form is said to have been discovered by David Douglas in 1825 near the mouth of the Columbia River in Washington. The first technical name of this tree, *Pinus contorta* Loudon, was published in 1838. The accompanying description was based on the stunted Pacific coast form raised from seed which David Douglas introduced into England in 1831.[2] The high-mountain form of lodgepole pine was first described and named "*Pinus murrayana* Oregon Committee" in 1853 and was found by John Jeffrey in 1852 in the Siskiyou Mountains, northern California. Ever since it was proposed to separate these two geographic forms of lodgepole pine the botanical history has been exceedingly complicated and includes the application by different authors of some 15 specific and varietal names, together with several erroneous references of the tree to other distinct species of two-leafed pines. Wide variation in the size of the cones and in the leaves has, for the most part, been the basis of confusion, which the present writer believes is best and properly cleared up by uniting all forms of the tree as one species.[3]

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[1] History of expedition under command of Lewis and Clark, ii, 457 (ed. Coues). It is believed that the pine mentioned in the narrative of these explorers, "a small species of pitch pine with a short leaf," could be no other than our lodgepole pine.

[2] Fide Sargent, Silva, XI, 93, 1897.

[3] The high-mountain form of lodgepole pine was introduced into cultivation in England in 1853 and 1854 by John Jeffrey, who sent seeds from the California Sierras (fide Elwes and Henry, op. cit., 1138, 1910). The Pacific coast form did not appear in cultivation there until 1885, when it was catalogued by Lawson as "*Pinus Mackintoshiana*" (Masters, Journ. Linn. Soc. (Bot.) XXXV, 647, 1904), although Douglas discovered the tree in 1825. Both forms appear to be hardy in England, where Elwes and Henry (l. c.) mention trees ranging in height from 40 to 59 feet. One tree grown from seed of the coast form attained a height of 28 feet in 20 years, while examples of the high-mountain form reached a height of 30 feet in 25 years. Both forms of lodgepole pine are said to be cultivated in Belgium; and extensive trials of them for forest planting are being conducted in Germany, where, however, this tree is reported to be affected somewhat by frost when planted in moist situations. Prof. C. S. Sargent (Gard. and For. X, 471, 1897) states that trees from Colorado planted in the Arnold Arboretum, near Boston, Mass., about 1877 have proved hardy in New England. The interior high-mountain form of this species was extensively planted in forest stands at the Letchworth Park Forest and Aboretum, in Wyoming County, N. Y., from 1912 to 1914, and so far the young stock appears to be adapted to the soil and climate there. It is, however, too soon to judge of its fitness and value as a forest tree for that region. For ornamental planting lodgepole pine has little to commend it because of the open appearance of the crown and its short, unattractive leaves.

DISTINGUISHING CHARACTERISTICS.

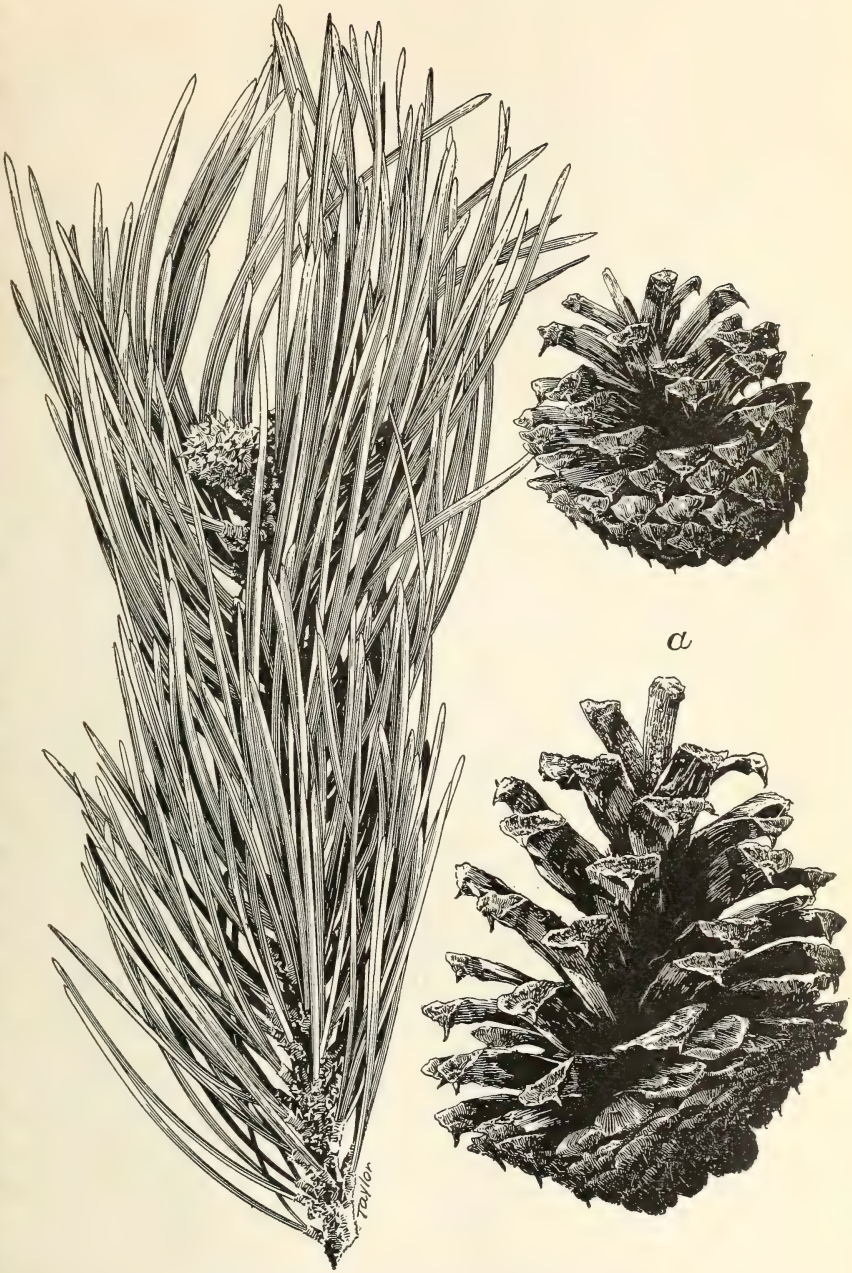
In the Pacific slope region this pine grows in rather open stands and forms a dense rounded or pyramidal crown of large, much-forked branches which often extend down to the ground. In its high mountain range within the Rocky Mountain region it grows in very close stands and develops a tall, clean, slender shaft with a short, rounded, small-branched crown. This characteristic form in its more eastern range has given the tree the name of "lodgepole pine." The thin scaly trunk bark is pale brown with a grayish tinge. In close stands the height is from 50 to 100 feet, the usual diameter being from 12 to 24 inches. Taller and larger trees sometimes occur. The smooth looking trunks are clear of branches for from 30 to 60 feet.

The foliage is a bright yellow-green. The leaves (Pls. XXVI, XXVII) are borne in bundles of 2 and are nearly one-eighth of an inch wide and from about 1 inch to nearly 3 inches long, but usually they are about 2 inches long. Each season's growth of leaves remains on the trees for from 6 to 8 years. Young trees, however, sometimes retain their leaves for 9 years. The edges of the leaves bear minute sharp teeth (serratures). A cross section of the leaves shows one or two resin ducts.

The cones (Pls. XXVI, XXVII) ripen late in August and September of the second season. On many trees, the cones open in late autumn and shed nearly all of their seeds, while the cones of other trees in the same locality may remain closed for a number of years. The cones adhere to the branches for a great many years, some of the closed ones finally opening and liberating their seed.[1] When the cones are fully ripe the tips of their scales are shiny and of a clay-brown color, the inner or unexposed portion being a bright purple-brown. The seeds (Pl. XXVII, *b*) are a deep reddish-brown, with black-brown spots. The seed-leaves vary in number from 3 to 6, but usually there are 5 (Pl. XXVII, *a*).

The wood of trees grown in dense stands, as in the Rockies, is extremely narrow-ringed; while that of trees in open forests, as in the Pacific region, is moderately wide-ringed. The thick layer of sapwood is almost white and the heartwood is of a clear yellow or yellowish-brown color; the heartwood of the Pacific coast form is usually pale brown tinged with red. The wood is rather hard, stiff, and straight-grained. A cubic foot of the dry wood of the Pacific

[1] The wonderful reproductive power of this species on areas over which it has been killed by fire is dependent upon the ability of the closed cones to endure a fire which kills the trees without injuring their seeds. After fire, the cones open, shed their seeds on the bared ground, and a new growth springs up. Another remarkable adaptation insuring this tree against extinction by fire is its habit of producing fertile cones at the early age of from 7 to 10 years.



PINUS CONTORTA: FOLIAGE AND IMMATURE CONE.

a, Detached open cone.

PINUS CONTORTA: FOLIAGE AND OPEN CONES (ATTACHED).

a, Seedlings one month old; *b*, upper (left) and lower sides of seeds with wings.

coast form is rather heavy, being about 36¼ pounds, while wood of the Rocky Mountain form weighs about 25½ pounds per cubic foot. Tangentially ("bastard") cut boards have a distinctly pebbled appearance when planed.

In the Rocky Mountain region the wood of this tree is becoming more and more valuable for commercial purposes, which include construction lumber, much used locally, and railway ties. It is also used for corral poles, house logs, and fuel. In the Pacific region it is used principally for these latter purposes.

OCCURRENCE AND HABITS.

In the Rockies *Pinus contorta* occurs on high plateaus and benches in the vicinity of streams, mountain meadows, and lakes, on broad ridges, and on long gentle slopes and bottoms of stream-watered basins at elevations between 7,000 and 11,500 (Map No. 13). North and east slopes are more favorable than west slopes, while south slopes, except in sheltered coves, are least favorable for the growth of this pine. It avoids limestone, but is adapted to dry gravelly soils, seeming to prefer sandy moist ones of gentle slopes, depressions, and plateaus, where the largest growth occurs. Stunted forms grow persistently, however, in crevices of solid rock. It forms extensive pure forests, particularly about meadows; on higher, rocky, rough ground it is sometimes associated with Engelmann spruce, aspen, Douglas fir, and alpine fir.

The lodgepole pine is very intolerant of shade, especially when young, but is able to maintain itself for a long time (from 20 to 50 or more years, or for a longer period) in very dense stands, after which, if wholly relieved from overhead shade, it recovers and grows rapidly. It grows best, however, in full enjoyment of light. Even-aged, dense stands with full top light, such as commonly follow complete destruction of the preceding growth by fire, may thrive for 50 or 60 years with little natural thinning out. But the prompt natural thinning out of overtopped trees at earlier stages in uneven-aged stands is proof that this pine is unable to endure longer continued shade.

This species is usually a prolific annual seeder, bearing large numbers of cones. The seed has a high rate of germination and persistent vitality. Fertile seeds are often borne by trees only from 6 to 10 years of age when growing in the open. In crowded stands cones are borne by trees from 15 to 20 years old. The small light seed is widely disseminated by wind, sometimes being carried 200 yards from the mother trees. Squirrels and birds destroy great numbers of the seeds, but the effect on reproduction appears to be inappreciable. Extension by natural seeding on unburned areas is ordinarily slow,

scant, and uneven; but reproduction on burned-over lands is, with aid of fire (which opens the cones), exceedingly thick and even. Full light and exposed mineral soil are requisites of good reproduction. This favorable condition of the soil is produced by fire, which, when it does not consume the cones, leaves them open or in condition to open and release their seeds.

LONGEVITY.

Lodgepole pine attains an age of from 100 to 175 years, but doubtless it is capable of reaching from 200 to possibly 300 years, if protected from fire, to which it quickly succumbs on account of its thin bark. Few stands have in the past attained an age of over 60 years before being killed by forest fires.

JACK PINE.

Pinus banksiana Lambert.

COMMON NAME AND EARLY HISTORY.

Pinus banksiana does not occur within our Rocky Mountain region, but it enters the Canadian territory immediately north of this region (map No. 14) and it is included here in order to present an account of all the pines in the Rocky Mountain region irrespective of national boundaries.

Jack pine is best known to the public as a tree of southeastern Canadian provinces and of our Great Lakes country, where it is variously called jack pine, scrub pine, black jack pine, gray pine, black pine, Banksian pine, and Hudson Bay pine. The name jack pine is, however, widely used and perhaps the most appropriate.

There appears to be no authentic record of when jack pine was first discovered. It must have been well known to the French explorers and settlers of eastern Canada at least as early as the sixteenth century. Strangely enough the first record of its existence is based on trees cultivated in England,[1] where the species is believed to have been planted prior to 1735. By whom and from what part of its range in this country the seeds or plants were sent to England is unknown. It seems likely, however, that seeds were sent from eastern Canada. The first technical name, *Pinus sylvestris*, ϐ *divaricata* Aiton, given to this tree was published in 1789 by William Aiton, a Scottish botanist and gardener, who based his brief description of it on trees growing in the Royal Botanical Garden at Kew, England, of which he was then director. Correctly speaking, the logical name for this pine should be *Pinus divaricata* (Ait.) Du Mont de Courset, which is based on this early one of Aiton. But

[1] Loudon, Arb. et Frut. Brit., iv, 2192. 1838.

in accordance with the international rules of nomenclature adopted at Vienna, Austria, in 1905, *Pinus banksiana* of Lambert (1803) is the proper name for this pine. Fortunately, this is the technical name under which jack pine was known to botanists from 1803 to 1892, *Pinus divaricata* having been revived in this country at the latter date and maintained until about 1905. Three other technical names, now reduced to synonymy, were also added during a botanical history extending over a centry and a quarter.[1]

DISTINGUISHING CHARACTERISTICS.

Jack pine varies in height from a stunted shrubby form only a few feet high to straight well-formed trees from 25 to 60 feet in height and from 8 to 20 inches in diameter; occasional trees reach a height of from 75 to 90 feet and a diameter of about 2 feet. Commonly, however, it is from 25 to 30 feet high and about a foot in diameter. The trunks are clear of branches for one-third or one-half the total height; in very dense stands longer clear trunks are common. Young trees are rather densely clothed down to the ground with noticeably slender branches, which, as a rule, trend sharply upward, forming a pointed oval-shaped crown, which is relatively narrower in a dense stand than in an open one. As the trees grow older, the crown becomes open because the longer, middle-crown and lower-crown branches spread widely or curve downward, and sometimes upward at their ends. The branches are strong and the twigs are notably tough and flexible. Twigs of a season's growth are smooth and light yellowish green, which changes to a deep reddish or purplish brown by the second season; the scaly terminal buds, three-sixteenths to one-fourth of an inch long and about one-eighth of an inch in diameter, are a dark cinnamon-brown. The thinnish dull red-brown bark of mature trunks is narrowly ridged and furrowed, the main irregular ridges being connected by smaller lateral ones.

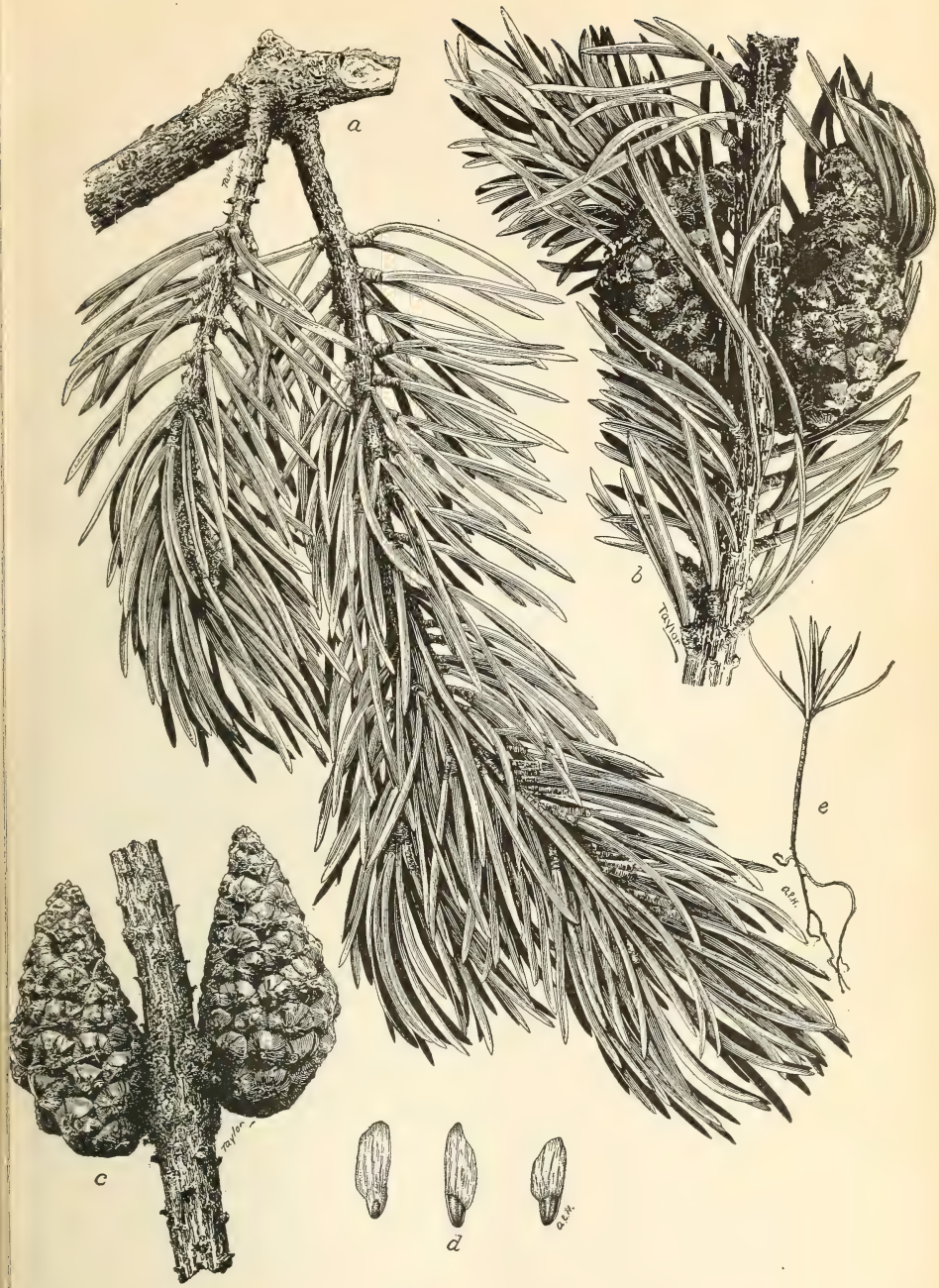
Compared with its frequent associates, the Norway pine and white pine, this species has strikingly thin foliage, which is due to its short distantly-set leaves. Fully matured leaves are a deep grayish green,

[1] There is no definite record of when *Pinus banksiana* was first introduced into cultivation in England, but it is believed to have been planted there some time prior to 1735. The few trees now growing there, some of which were planted as early as 1839 to 1850, had in 1909 attained heights of from 35 to 40 feet (fide Elwes and Henry, op. cit., 1112). Many trees planted in England during these early years have gradually disappeared, which, in the opinion of Elwes and Henry, indicates that the species is not well adapted to the climate there. It has been extensively planted in Germany by the Government, and to some extent also in Russia, where the trees made remarkably rapid growth during youth. As might be expected, however, this species gives little or no promise for the production of useful timber, its greatest usefulness being to form a tree cover on exceedingly poor sandy and gravelly land where good timber trees will not grow. In the United States, jack pine is one of the few conifers that has been successfully established in the sand-hill region of western Nebraska, where the conditions for tree growth are exceedingly unfavorable.

and those produced each year remain on the branches until about the third summer; in some instances, however, many of them die and fall from the trees during the second season. They are usually curved, and are borne in bundles of two (Pl. XXVIII, *a*, *b*). In length they vary from about seven-eighths of an inch to nearly 1½ inches, but commonly they are about an inch long. The edges of the leaves bear minute and widely-separated teeth (serratures). A slightly magnified cross section of the leaf shows, as a rule, two resin ducts, one in each angle of the section (edge of leaf); occasional leaves appear to be without resin ducts.

The characteristically one-sided cones (Pl. XXVIII, *b*, *c*) are fully mature by September of the second season, and two, three, or four of them may be borne in one cluster. They vary in length from 1¼ to about 2 inches and from one-half to nearly 1 inch in diameter at the thickest place. Early in autumn they are a greenish to a deep purple, but later they turn to a light clay-brown, the ends of the closely pressed cone scales being shiny. During the first season the scales of young cones bear delicate curved prickles, which, however, usually disappear or are very inconspicuous by the time the cones are ripe. A characteristic habit of the cones of this pine is to remain attached to the trees for from 12 to 25 years or more. The cones are peculiar also in that they open irregularly and liberate only a few of their seeds at a time and then usually only after the cones have remained closed for two or three years. The triangular seeds are from one-eighth to three-sixteenths of an inch long and about three thirty-seconds of an inch wide, and are covered with a blackish-brown minutely pebbled membrane, tiny bits of which become detached and show the light yellow-brown shell of the seed beneath. The upper side of the seed is more or less distinctly marked with two grooves. The seed-leaves vary in number from four to five (Pl. XXVIII, *e*; lowermost long leaves).

Jack pine wood is variable in texture and weight from rather soft and light to rather hard and moderately heavy, some grades of the wood being nearly of the same hardness and weight as Norway pine. A cubic foot of dry wood weighs about 29¾ pounds. When seasoned it is brittle and weak and decays rapidly in contact with earth. The sapwood is thick and of a uniform pale creamy white, but the heartwood varies in color from a bright, slightly brownish yellow to a light yellow-brown. The wood formed during the first 15 or 20 years, when the tree grows rapidly, is moderately wide-ringed; that formed during the remainder of the tree's life, when diameter growth is very much slower, is narrow-ringed—sometimes exceedingly so. Little is known now regarding the use, if any, of this timber in the far northwestern range of the tree. In the central and eastern parts



PINUS BANKSIANA.

a, Foliage; *b*, *c*, clusters of closed cones; *d*, seedling one month old; *e*, seedling.

of its range, where formerly this pine was very abundant, the wood was but little used, except locally for fuel, light-traffic ties, and occasionally for rough lumber. In recent years, however, the scarcity and high cost of other northeastern pines has led to extensive commercial use of jack pine lumber wherever the trees are large enough to be milled. Logs as small as 6 inches in diameter are now cut into rough slack-cooperage stock and lumber for packing cases. Heavy "tongue-and-grooved" jack pine planking, used for roofing under a waterproof covering and for various other similar purposes, has been entering our northeastern markets more and more of recent years, but usually under an assumed name. The so-called "Hudson Bay pine," purporting to come from a far northern source, is in some instances jack pine. Clear grades of jack pine are so similar in appearance and working qualities to Norway pine that they could probably pass for Norway pine. For the most part, however, jack pine produces a low-class knotty lumber unfit for the better uses to which Norway pine is put.

OCCURRENCE AND HABITS.

Jack pine is essentially a tree of barren sandy or rocky land throughout its wide range (Map No. 14). It occures also, however, in moist soils of good quality, which, if well drained, produce the largest trees. The vertical range of jack pine is between about 100 and 1,200 feet above sea level. For the most part it forms either small scattered patches or extensive bodies of pure growth. In its eastern range *Pinus banksiana* is associated more or less with white pine, and to some extent also with Norway pine. The mingling of these species occurs chiefly when the jack pine begins to decline, the red and white pines later generally crowding it out. Jack pine is decidedly intolerant of shade at every period of its life except during the first year or two of seedling growth, when it bears light shade, but with some loss of vigor.

Pinus banksiana is an abundant seeder, some seed being borne practically every year, but specially heavy seed production occurs at intervals of about 2 or 3 years. Trees in an open stand often begin to bear cones when they are only a few feet high (10 to 12 years old);[1] trees in a dense stand begin to bear when about 25 years old. The seed has a very high rate of germination (from 60 to 80 per cent) and persistent vitality. Reproduction is usually scattered, owing doubtless to the irregular and tardy opening of the cones, but the precocious seed bearing results in gradual and constant extensions and the filling out of openings in thin stands of this tree.

[1] Near relatives of the jack pine, *Pinus contorta, P. virginiana,* and *P. clausa,* have the similar habit of producing cones at a very early age.

Moreover, the habit this tree has of long retaining its cones in a closed state enables the species to perpetuate itself even after severe fires have killed the mother trees, because, if not too badly burned, many of the charred cones then open and liberate their seed. Vast areas in the central and eastern parts of its range once heavily stocked with *Pinus strobus* and *P. resinosa* are now re-covered with jack pine, which is often the only growth on these barrens.

LONGEVITY.

Jack pine is comparatively short-lived, the largest trees probably not exceeding from 125 to 150 years of age. As a rule, however, the age of such trees can not be determined accurately, because they are decayed at the heart. The oldest sound trees ordinarily cut rarely exceed 110 years in age. Trees from 6 to 15 inches in diameter grown in an open stand are from 25 to 85 years old, while 6-inch trees grown in a dense stand are from 70 to 75 years old.

KEY TO SPECIES.

Leaves borne singly (or some of them 2 in a bundle)_____ *Pinus monophylla*
Leaves borne in bundles of 2:
- Cones armed with delicate prickles_____ *Pinus contorta*
- Cones without prickles—
  - Cone scales widely open after the cones are ripe_____*Pinus edulis*
  - Cone scales mostly closed, or only part of them open, after the cones are ripe_____ *Pinus banksiana*

Leaves borne in bundles chiefly of 3 (sometimes in bundles of 2, 4, or 5):
- With a prominent basal sheath—
  - Cone scales armed with stout prickles—
    - Leaves mostly from about 4 to 7 inches long_____ *Pinus ponderosa*
    - Leaves mostly from about 8 to 15 inches long____ *Pinus apacheca*
- Without a basal sheath:
  - Cones borne on long, slender stems_____ *Pinus chihuahuana*
  - Cones borne on very short stems_____ *Pinus cembroides*

Leaves borne in bundles of 5 and cones with prickles:
- Cone scales armed with long, delicate prickles_____*Pinus aristata*
- Cone scales armed with short stout prickles_____*Pinus arizonica*

Leaves borne in bundles of 5 and cones without prickles:
- Cones opening at maturity and shedding their seeds—
  - Cone scales strongly reflexed at the tips_____ *Pinus strobiformis*
  - Cone scales mostly not reflexed at their tips—
    - Seeds with long, well-defined wings_____ *Pinus monticola*
    - Seeds with very short rudimentary wings_____ *Pinus flexilis*
- Cones remaining closed at maturity_____ *Pinus albicaulis*

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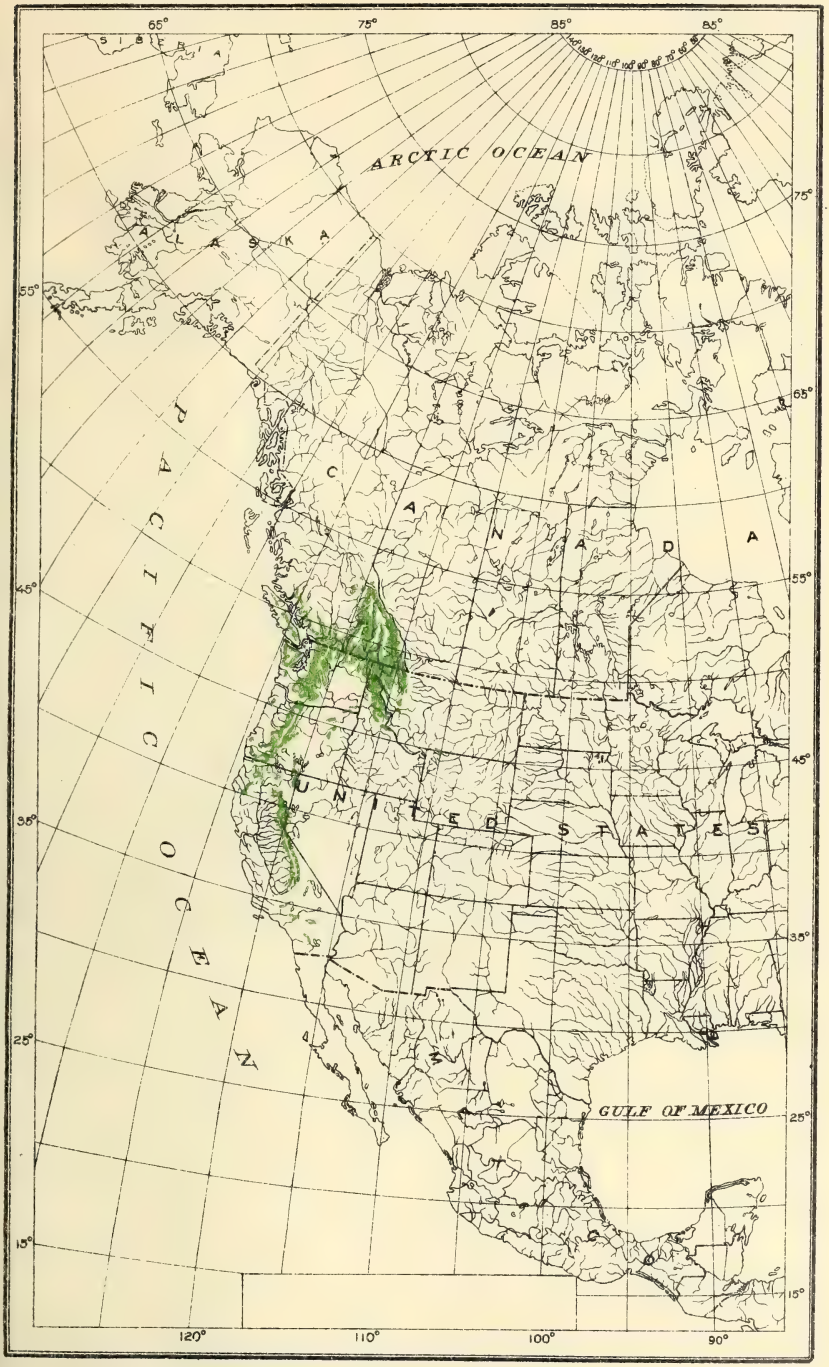

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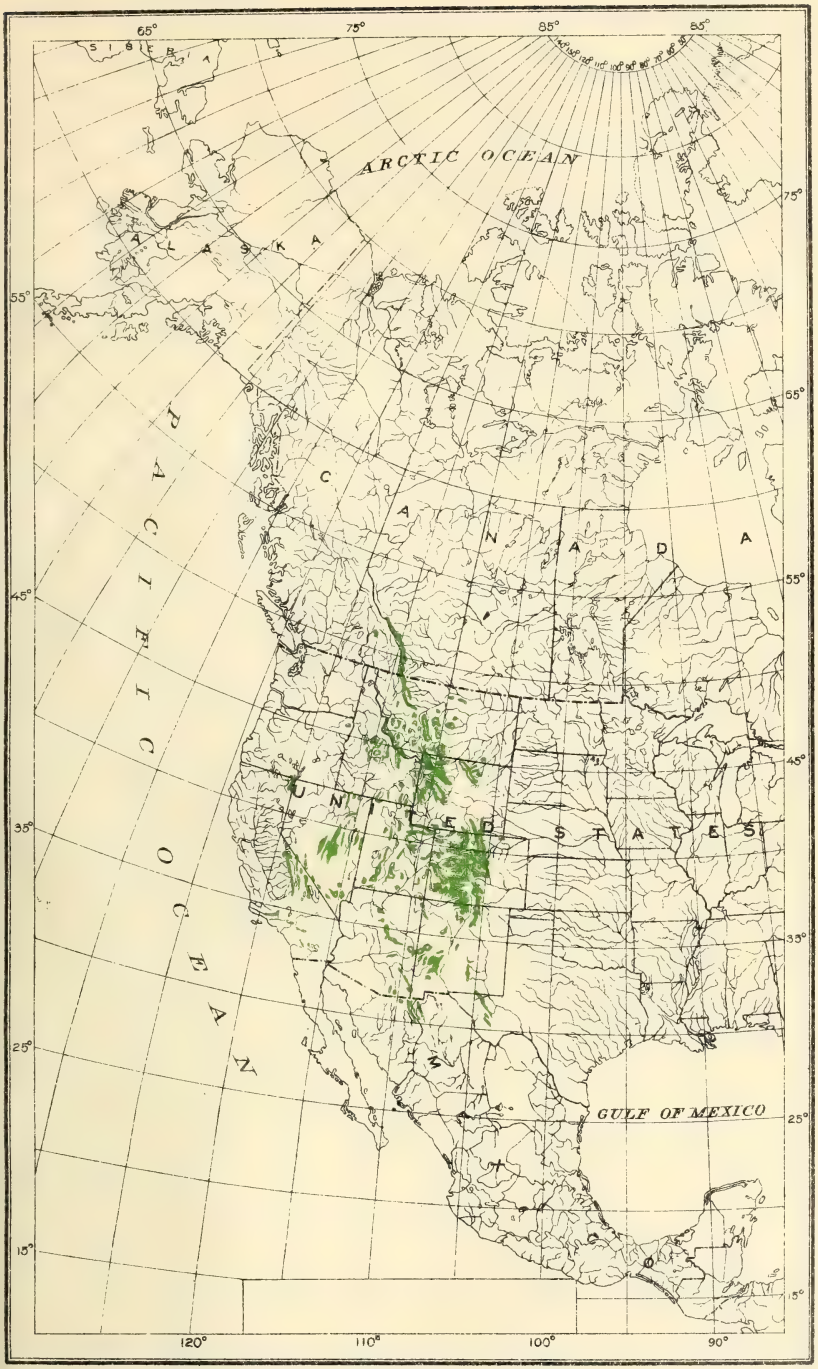

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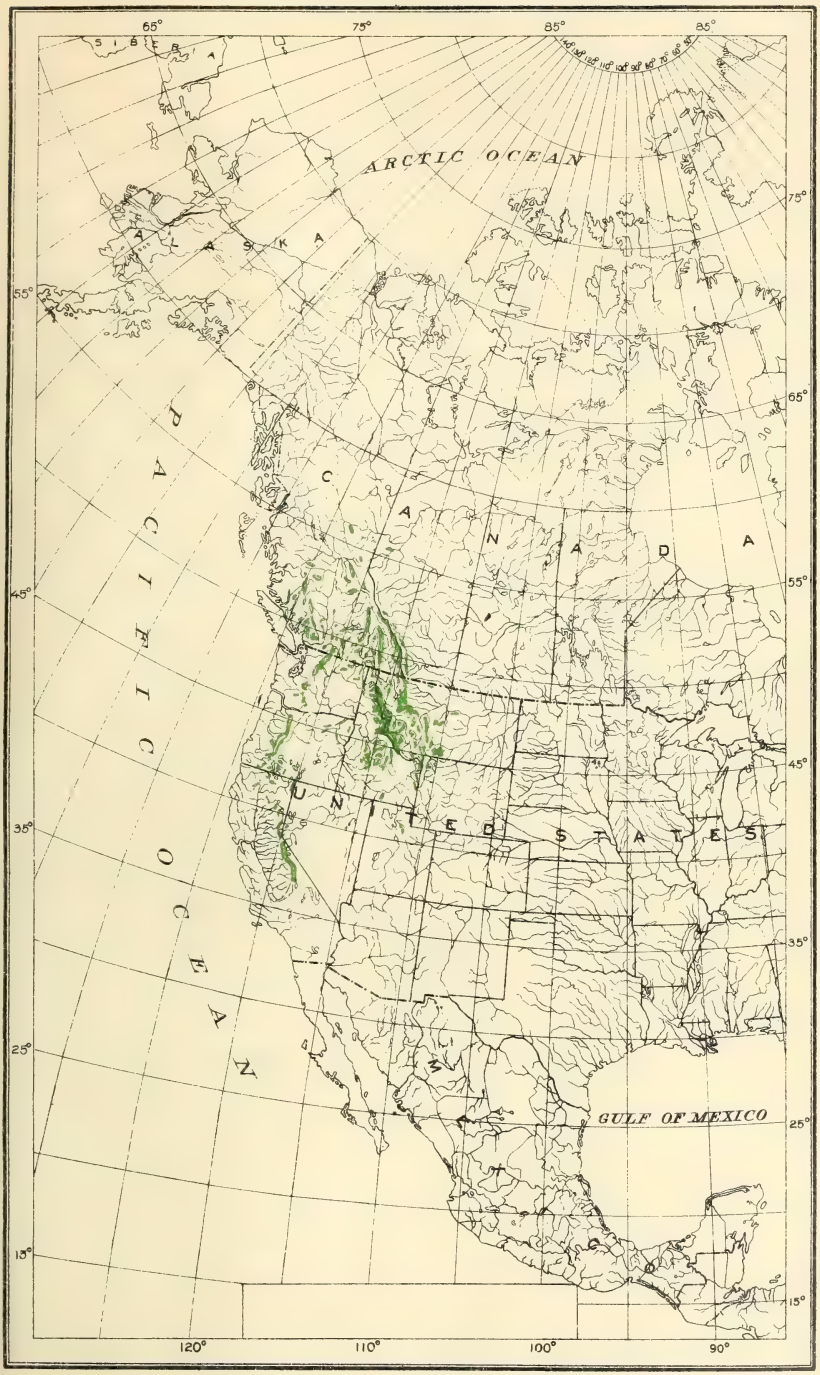

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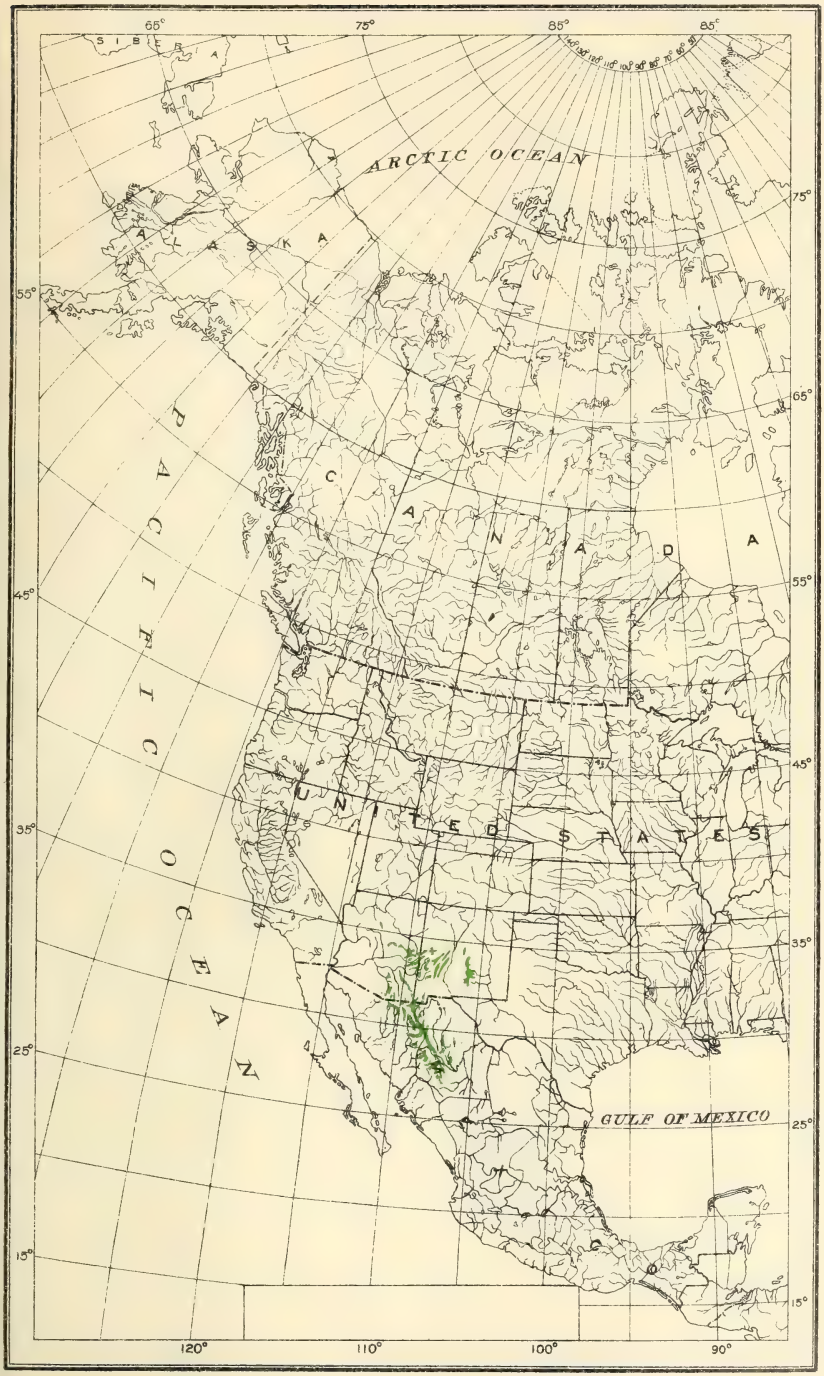

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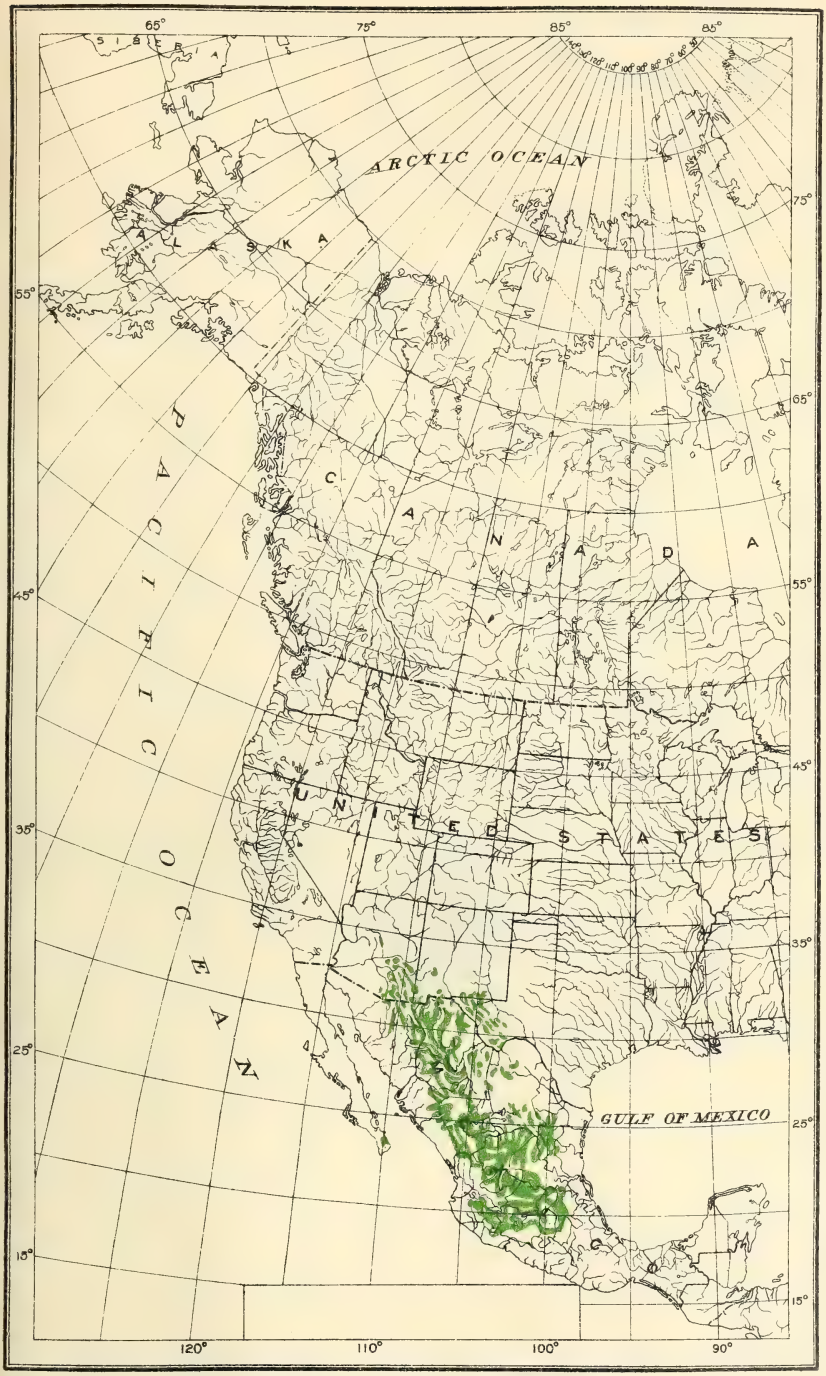

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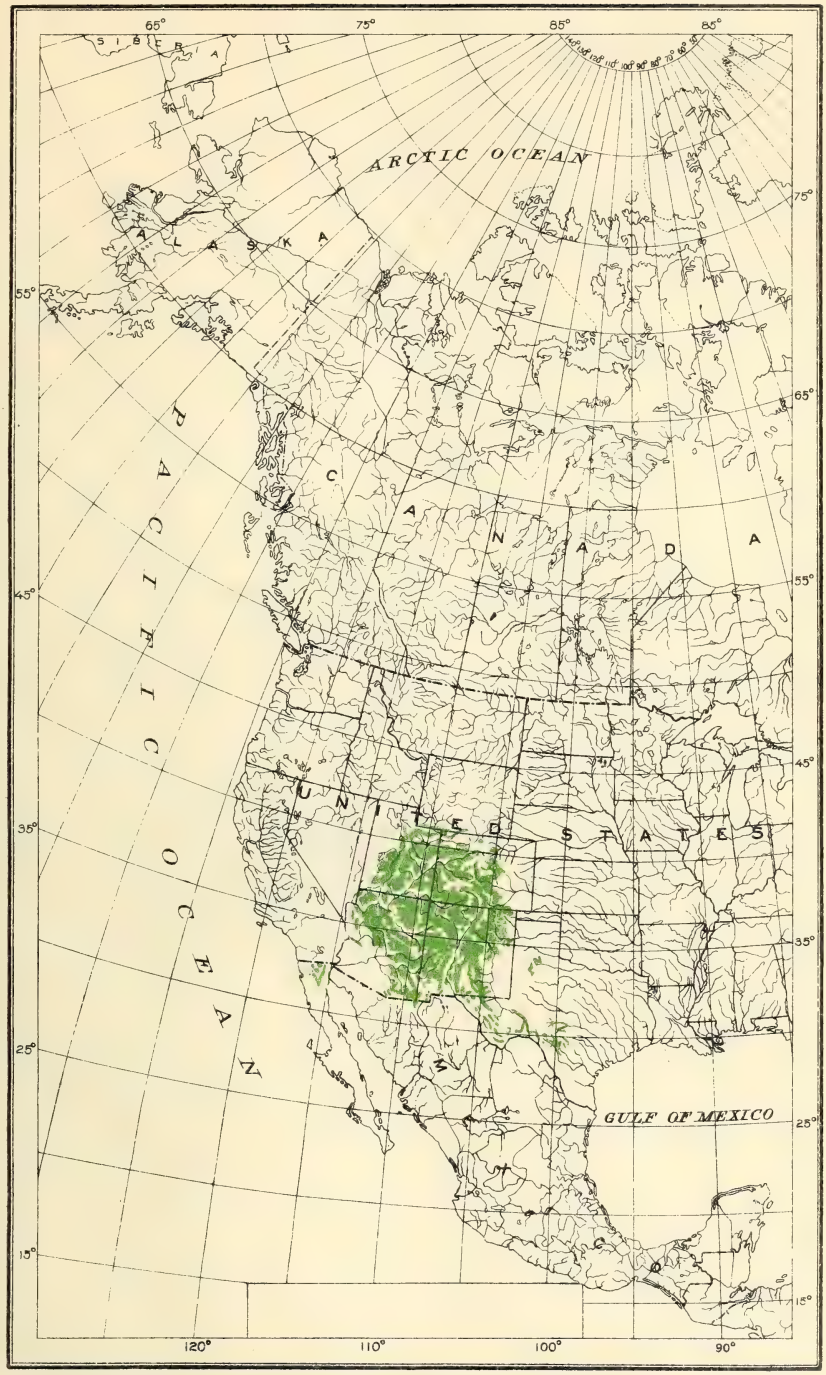

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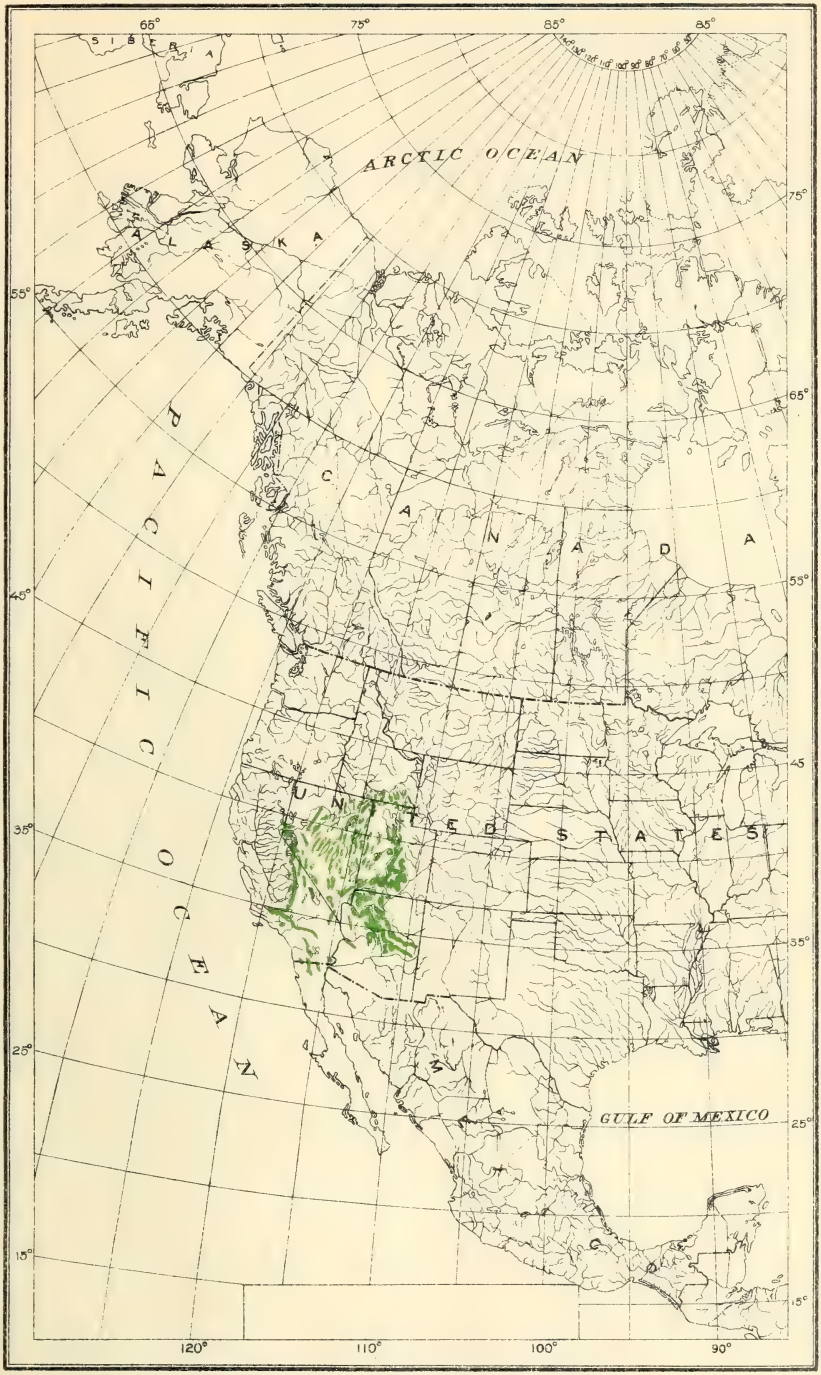

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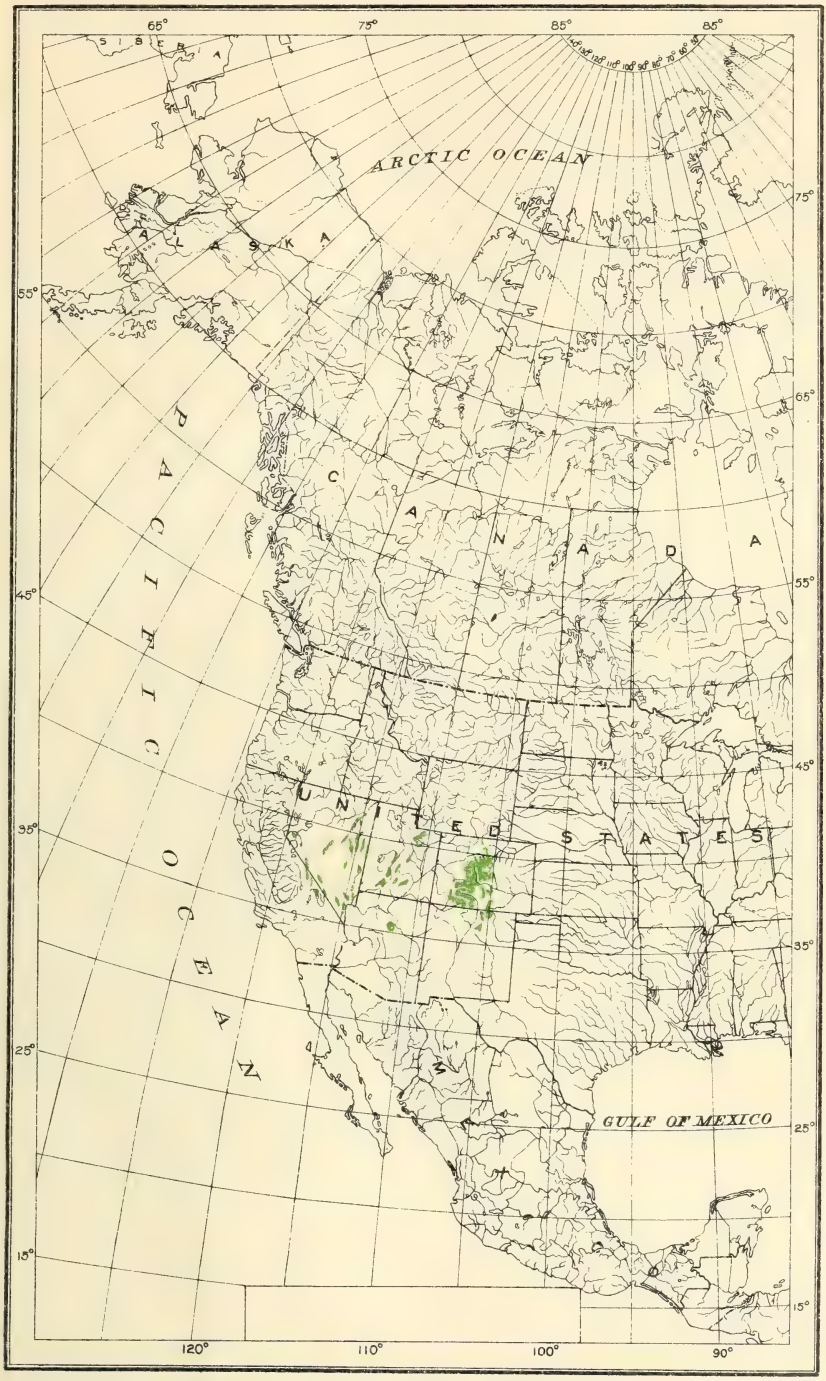

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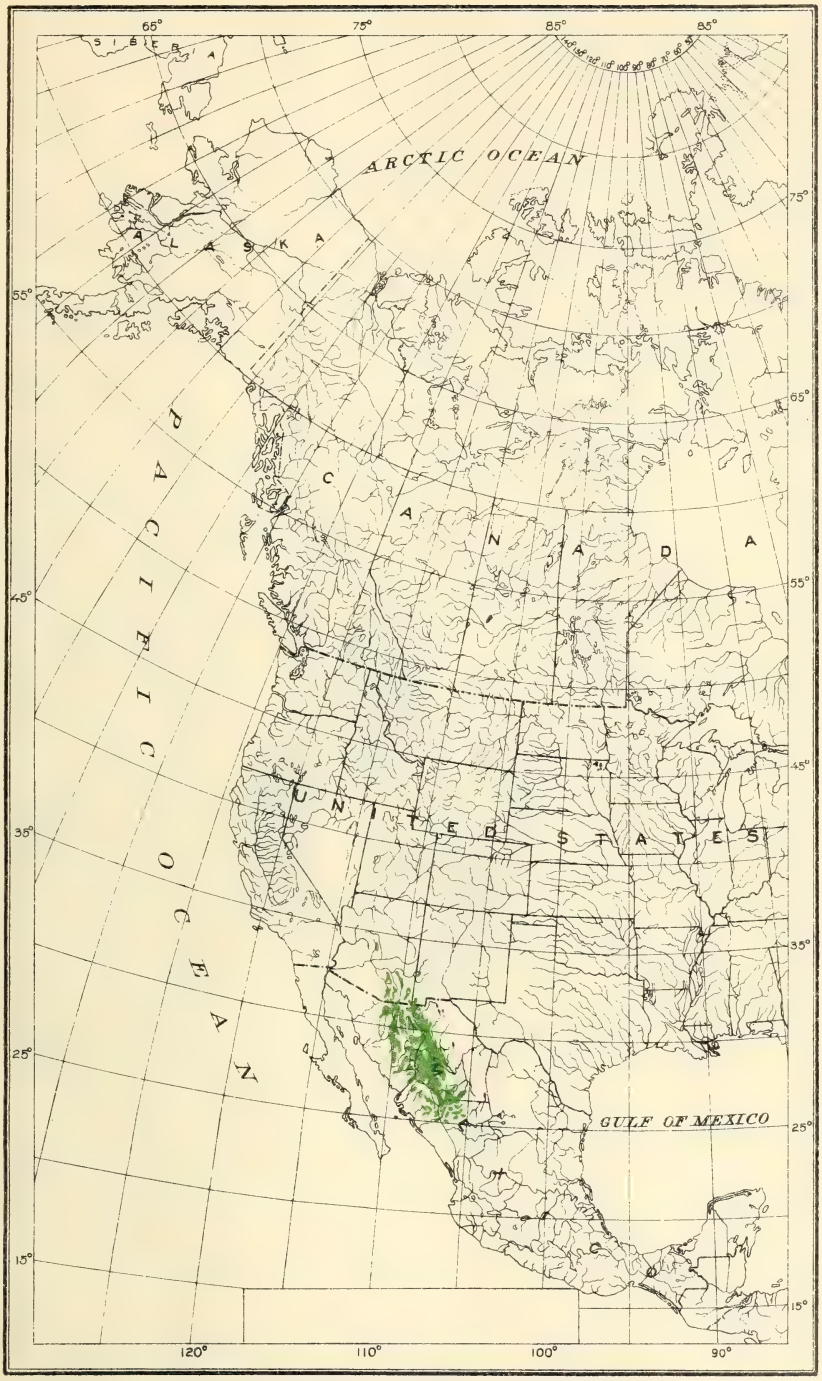

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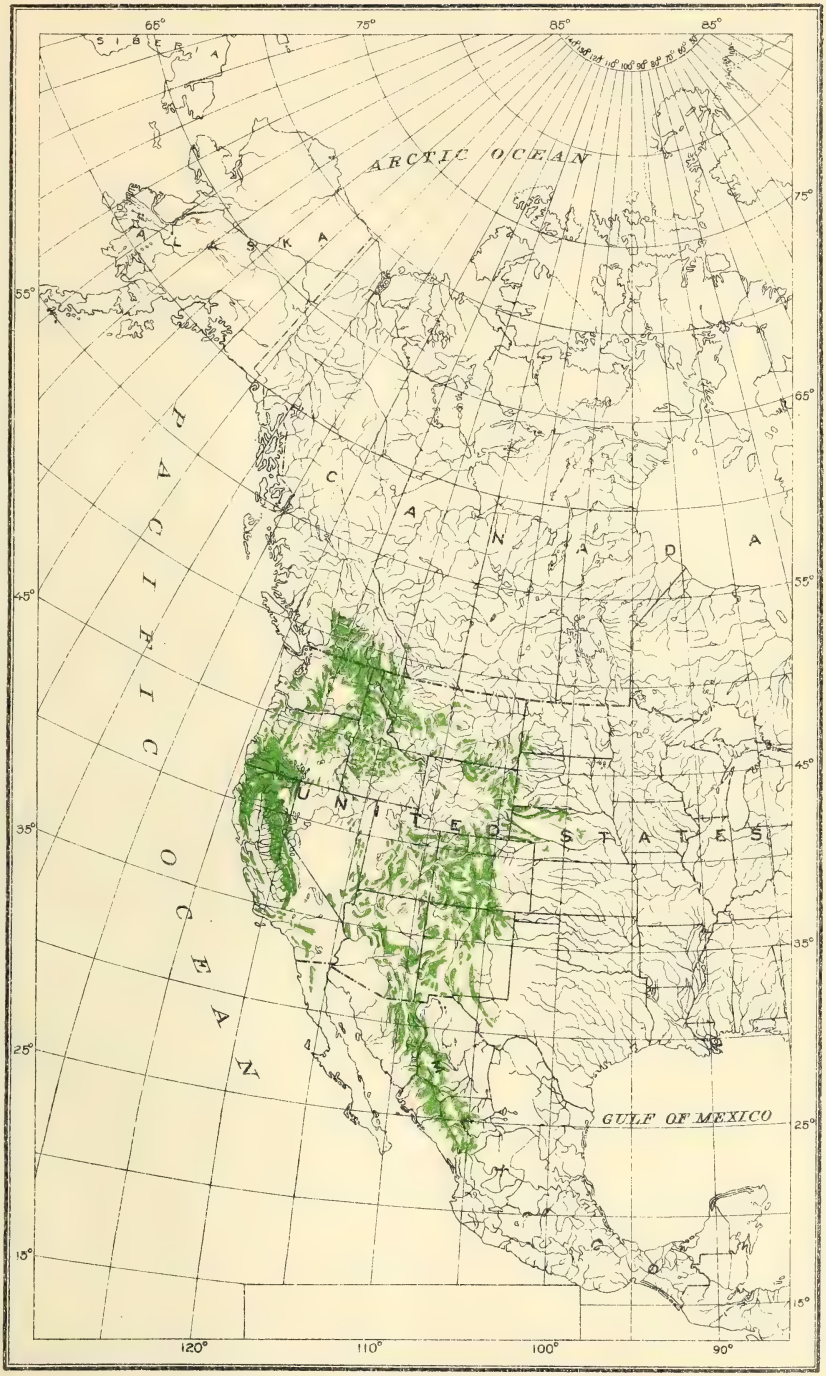

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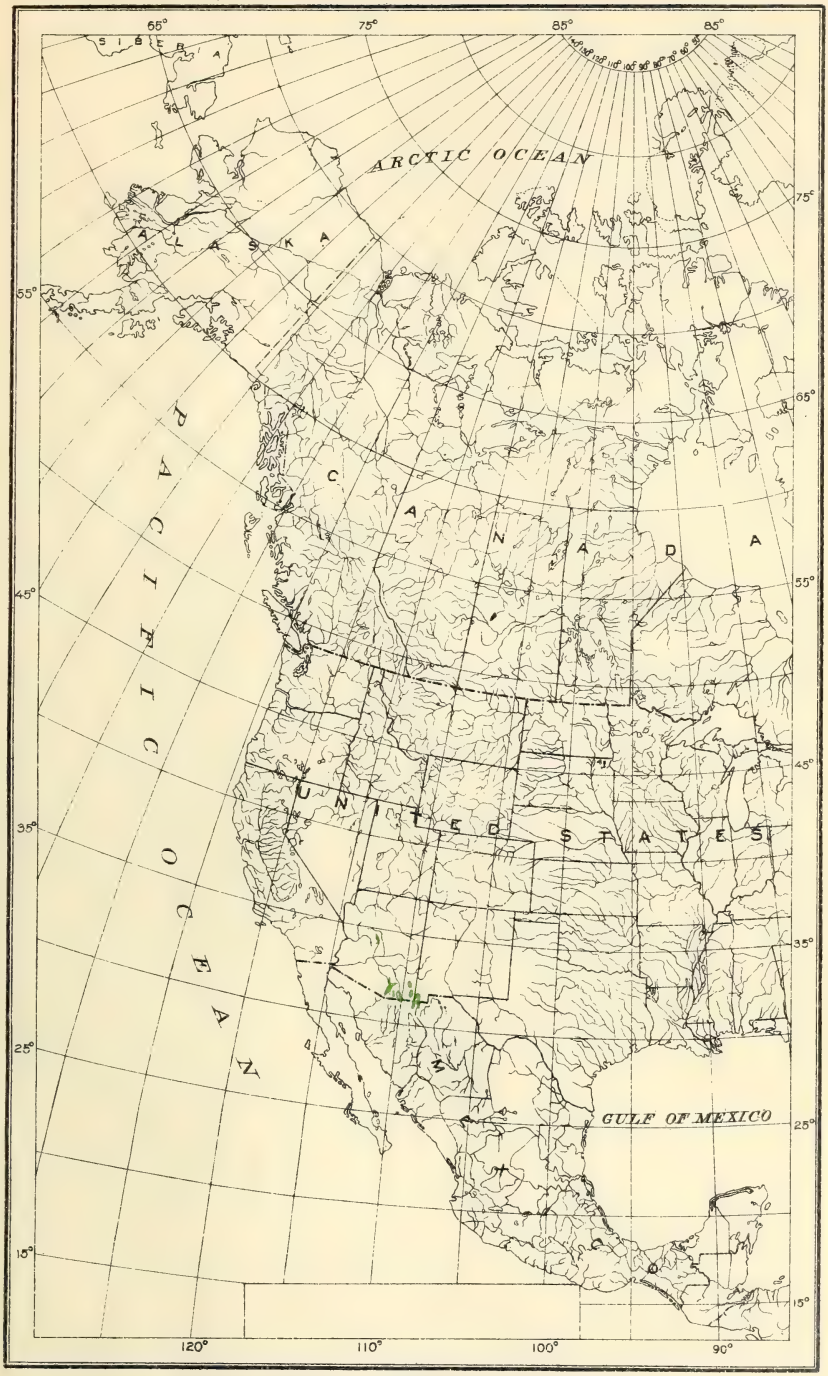

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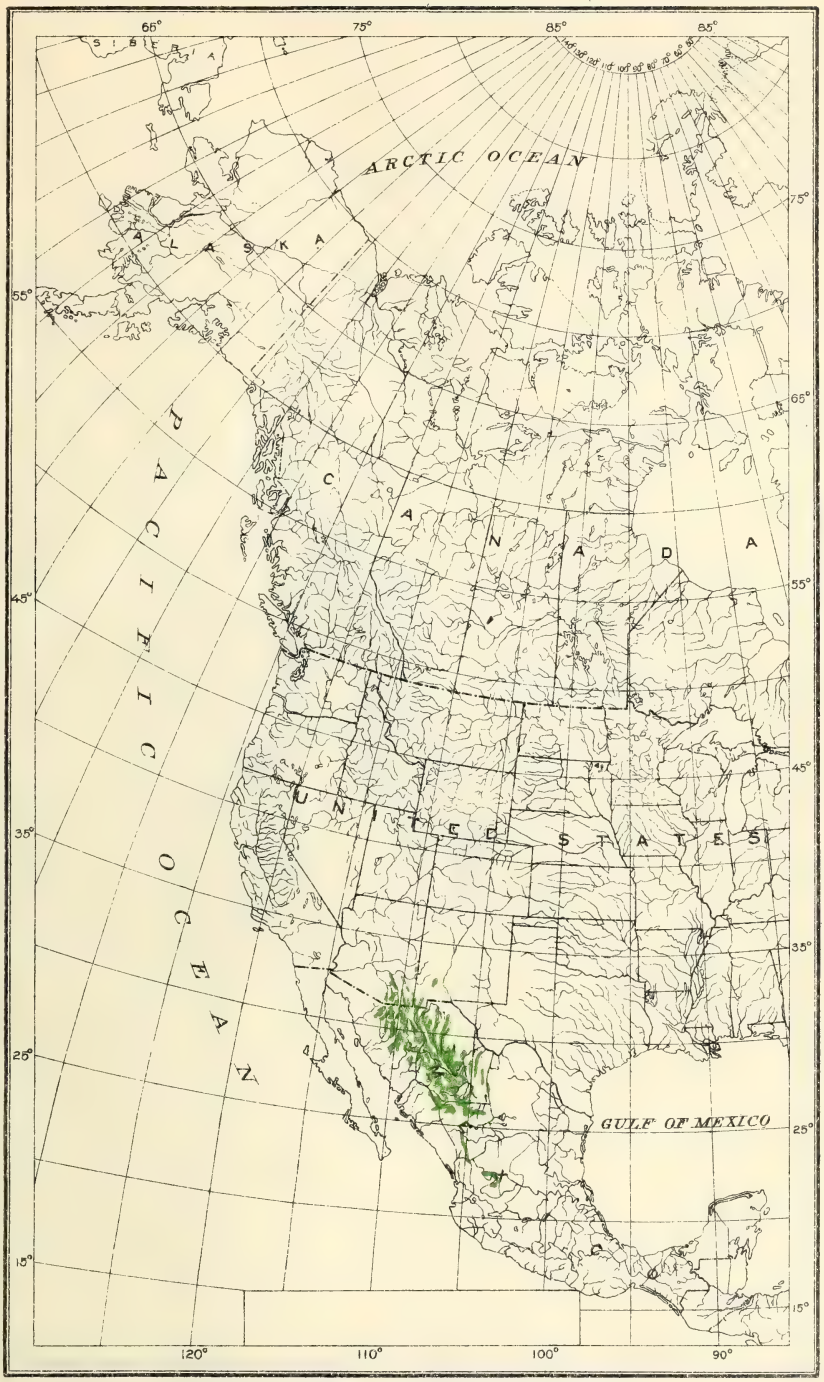

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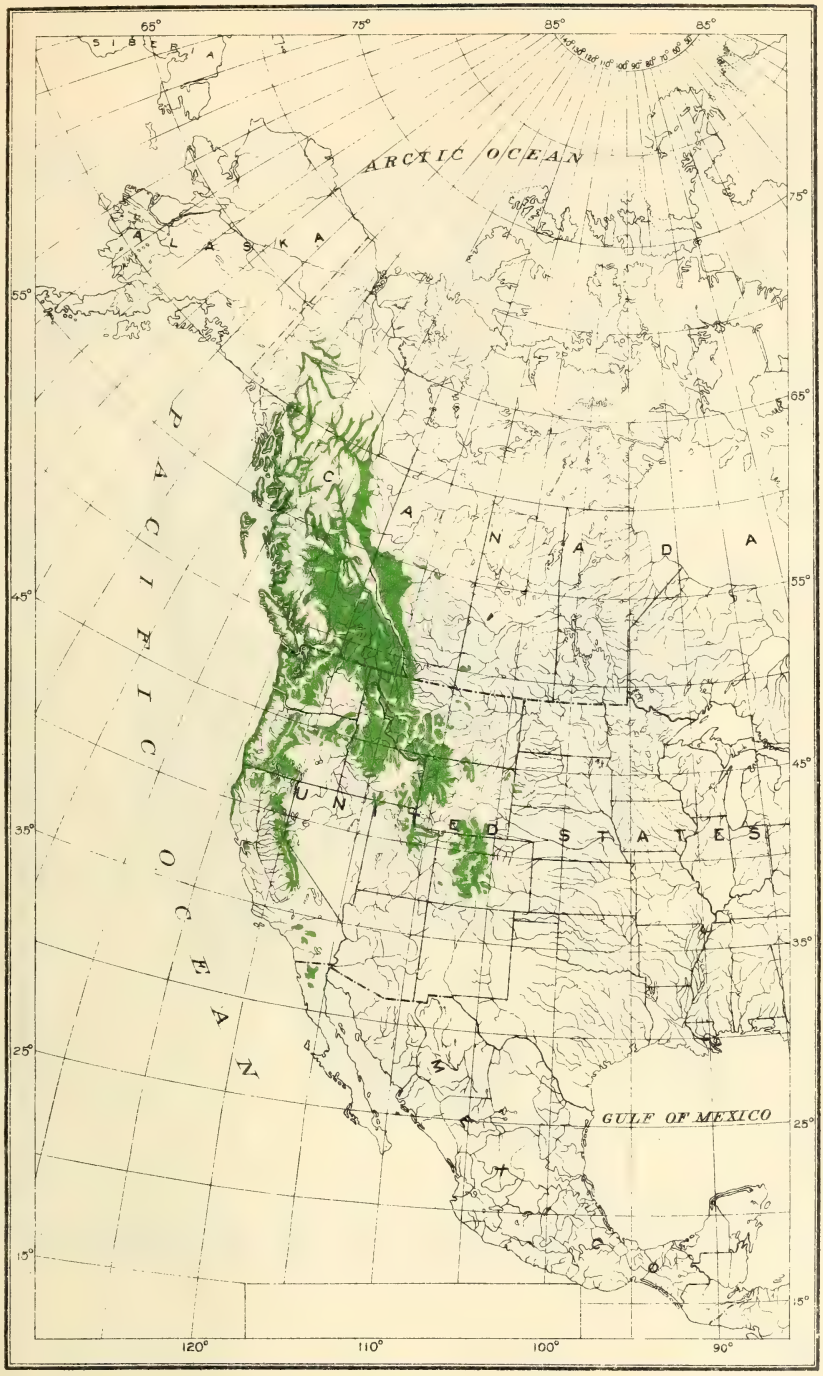

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